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South Carolina Univ., Columbia

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Evaluation of Selective Erosion Control Techniques

Piedmont Region of S.E. United States

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Following a severe rain, during the period before the establishment of a dense grass cover, it was found that the blanket products and straw mulches provided the soil with maximum protection from erosion. Some tackifiers were effective in stabilizing the fine fraction of the soil. Some hydromulches tended to be washed away and were not effective in inhibiting soil erosion.

Each treatment contained a standard lime, seed and fertilizer mixture to test the ability of the technique to produce a dense vegetative cover. After 8 to 12 weeks, the straw and blanket products produced a more dense vege[illegible]ver than the hydromulches and tackifiers. This was probably due to increased so[illegible]rface moisture afforded by the former as an insulating blanket.

With time, however, as lateral rhizome development of grasses took place, the soil protection was more readily afforded by the vegetative cover and all sediment yields decreased.

A cost analysis showed that some of the more successful treatments are too expensive to be applied routinely over large areas. The results of this study compared with those of other reported studies.

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EVALUATION OF SELECTIVE EROSION CONTROL TECHNIQUES

Piedmont Region of S.E. United States

by

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of the environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

Loss of soil to erosive forces of wind and water is accelerated during times when a rapidly growing population places increasing demands on the natural environment for housing, food, and energy. This investigation demonstrates the relative efficacies of a number of soil stabilizing and revegetation treatments that are commercially available for short-term stabilization of areas undergoing construction activities.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

Commercially available soil stabilizers, including chemical tackifiers, hydromulches and blanket (netting) products and combinations thereof, were tested in the Piedmont of South Carolina. The test site was designed to measure sediment yields to provide a quantitative assessment of treatment effectiveness.

Following a severe rain, during the period before the establishment of a dense grass cover, it was found that the blanket products and straw mulches provided the soil with maximum protection from erosion. Some tackifiers were effective in stabilizing the fine fraction of the soil. Some hydromulches tended to be washed away and were not effective in inhibiting soil erosion.

Each treatment contained a standard lime, seed and fertilizer mixture to test the ability of the technique to produce a dense vegetative cover. After 8 to 12 weeks, the straw and blanket products produced a more dense vegetative cover than the hydromulches and tackifiers. This was probably due to increased soil surface moisture afforded by the former as an insulating blanket.

With time, however, as lateral rhizome development of grasses took place, the soil protection was more readily afforded by the vegetative cover and all sediment yields decreased.

A cost analysis showed that some of the more successful treatments are too expensive to be applied routinely over large areas. The results of this study were comparable with those of other reported studies.

The report was submitted in partial fulfillment of Grant No. S-803724 by the University of South Carolina under sponsorship of the U.S. Environmental Protection Agency. This report covers the period May 1977 to January 1978, and work was completed as of July 1978.

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SECTION 1
SUMMARY AND CONCLUSIONS

This study was designed to test the effectiveness of a variety of soil stabilizing and revegetation treatments in the Piedmont of the southeast. The specific objectives were to:

(1) assess which of the commercially available techniques or treatments were most effective in inhibiting soil erosion.
(2) determine the efficacy and time for the treatments to establish a vegetative cover.
(3) attempt to ascertain the relative efficiencies and economic considerations of each treatment tested.

A parcel of land having a uniform slope and constant exposure was chosen within the Walden facility of the South Carolina Correctional Institute located approximately ten miles (16km) northwest of Columbia, South Carolina. A 15 acre (6.1 ha) site was subdivided into 24 test plots, each 30 feet (10 m) long with 90 to 150 feet (30 to 50 m) widths. All slopes had a 13% grade. The individual test plots were separated from each other by vinyl borders which served to prevent water from flowing between plots. In turn, each plot was subdivided into a demonstration portion, which would be used for visual comparisons, and a sediment yield plot. At the base of the latter, sediment and water volume collectors were installed to measure the sediment yields from each plot. All plots were hand raked to a uniform slope and treated to discourage volunteer vegetation.

The treatments tested were (1) four hydromulches (Conwed, Superior Fiber, Silva Fiber and Pulch), (2) three netting products (Jute, Hold gro and Excelsior blanket), (3) eight tackifiers (Curasol AK, Terra Tack III, Aerospray (or DCA 70), Crust 500, Dow mulch binder, Petroset SB, Perma Soil and Genaqua), used as prescribed with a standard wood mulch, (4) straw mulch tested with three chemical stabilizers (Curasol AK, Terra Tack II and Dow mulch binder) and one plastic net (Vexar). In conjunction with the treatments, all plots received a standard lime, seed and fertilizer mixture. Of the remaining five plots, three were treated only with a standard lime, seed and fertilizer mixture as a control and two were left disturbed with no treatment at all.

The sites, following installation, were routinely inspected and the sediment yields were sampled five times during the period from October 28, 1977 to January 23, 1978. The sediment yields were related to treatment effectiveness with regard to (1) soil stabilization prior to a full vegetative cover and (2) the ability of the treatment to quickly produce an adequate vegetative cover.

During the first 8 to 12 week period, at a time when the plots were bare and the vegetation had not become fully established, a high intensity rainfall occurred which severely tested the treatments' ability to protect the soil surface. It was found that some tackifiers were effective in protecting the fine grained portion of the soil, while some mulches tended to wash away. The blanket products and the straw covers gave the best protection. Straw applied as a ground cover without a tackifier seemed to exhibit natural ground security and did not wash away. Straw lightly tacked with a binder performed superbly.

Initially, large quantities of sediment were derived from the plots, but with time the amount of sediment decreased. This was due to (1) armoring of the soil surface by rain drop impact, (2) sheetwash and winnowing away of sediment source and (3) progressive development of vegetational cover. This suggests that the treatment applied is most useful during the early critical time when vegetation has not yet become established. After about 12 weeks, the grass cover became dominant and with lateral rhizome development afforded maximum soil erosion protection on all plots.

With the onset of vegetation, it was possible to assess which of the treatments afforded the best seed germination, plant growth and vegetative cover. It was found that the straw and blanket products provided the best environment for the establishment of vegetation. It appears that the failure of the hydromulches to start dense germination of seedlings was due to the inability of these products to provide sufficiently moist conditions during dry periods, the cost of blanket treatment per area basis is comparatively more expensive than the other treatments, which places an economic constraint on the extent of application.

Throughout the study, the trends that were initially established continued and although there was a decrease in the amount of sediment produced from each plot, the relative efficacies between treatments continued to be maintained.

The consistent trends which were obtained suggest that the methods of observation used were reliable and reflected treatment effectiveness.

All data derived from this study were transcribed to VM factors (see page 41) for comparison with results of similar studies in the literature. Results were found to be comparable to those of other studies.

SECTION 2

INTRODUCTION

The loss of soil to the erosive forces of wind and water is accelerated during times when a rapidly growing population places increasing demands on the natural environment for housing, food, and energy. As an example, since 1974 surface mining for coal, sand and gravel has created over 4.4 million acres of disturbed land in the United States, of which only 42% has been adequately reclaimed (12). In addition, urban development and highway construction have also been identified as major factors in creating soil loss conditions. Even short-term exposures of severely disturbed surface areas of construction sites result in large soil losses. These erosive conditions not only create situations conducive to soil destruction but, in addition, the soil that becomes detached and transported increases the turbidity of waterways, causes siltation of lakes and ponds, affects sedimentation of major drainways and culverts and in some cases may blanket, bury and choke the vegetation of periodically inundated areas.

Recently, an increasing awareness of these problems has led to the formulation and design of a variety of chemical and physical soil stabilizers that can be used to temporarily retard soil erosion while simultaneously providing a suitable medium for the establishment of protective vegetation. This report summarizes the results of a field study that was designed to demonstrate the effectiveness of a variety of soil ameliorants, mulches and tackifiers.

PURPOSE

The purpose of this investigation was to demonstrate the relative efficacies of a number of soil stabilizing and revegetation treatments that are commercially available for short-term stabilization of disturbed soil slopes. The products under discussion are designed to initially shield the soil surface from the erosive powers of rainfall and sheet runoff while promoting the establishment of a perennial vegetative cover suitable for the permanent stabilization of soil of the disturbed site. The specific objectives of this study were:

(1) To demonstrate the soil stabilizing techniques or treatments that are most effective in inhibiting soil erosion.
(2) To determine the efficacy of the treatments and the time required to establish a vegetative cover.
(3) To ascertain the efficency and economic considerations of each treatment tested.

TEST SITE

For obvious reasons, the proposed area of study had to be of public domain, accessible to visitors, reasonably close to Columbia, South Carolina, located within the Piedmont-type terrain and yet relatively secure from vandalism. The parcel of land that met all these criteria was found on a 15 acre (6.07 hectare) tract of land that was made available for our use by the South Carolina Department of Corrections. The project site is located north-northwest of Columbia in Richland County, South Carolina (Figure 1) and borders the southern extremity of the Southern Piedmont Province.

The site is comprised of three adjacent hillslopes with a predominantly southern exposure (Figure 1). The slopes are moderate, ranging from 9 to 14%. Prior to this study, the site was used primarily for pastureland and had a well-developed grass cover. Figure 2 shows the appearance of the site in mid-April, 1977 prior to the groundbreaking and slope modification that was necessary for the study.

The soil type underlying the test site is the Herndon silt loam. This soil is characterized by a loamy A horizon and yellowish brown and strong brown clay B horizon that contain more than 30% silt. The A horizon is a silt loam and averages 9 inches (22.8 cm) thick. The B horizon is a silty clay loam, silty clay or clay containing 35 to 50% clay, more than 30 to 40% silt and in some portions, fragments of partly weathered slate, shale or sericite schist. The C horizon may be white with varying shades of brown and red derived from the saprolite formed in the underlying slate, shale or sericite schist bedrock. Soil development ranges from 40 to 70 inches (100 to 175 cm) and the depth to unweathered bedrock is commonly more than 10 feet (30 m). In some areas, 15 to 20% of the surface is covered by quartz pebbles and stones. Although saprolite has developed to a depth of several feet, cores and fragments of hard rock are common (2).

Herndon soils commonly occur on gently sloping to strongly sloping Piedmont uplands. Slope gradients generally range from 6 to 12% and are well drained with medium runoff and moderate permeability. The average annual rainfall for the area is 46 inches (115 cm) and the average temperature is 64° F (17.8° C). Deep, well drained soils are characteristic of this area.

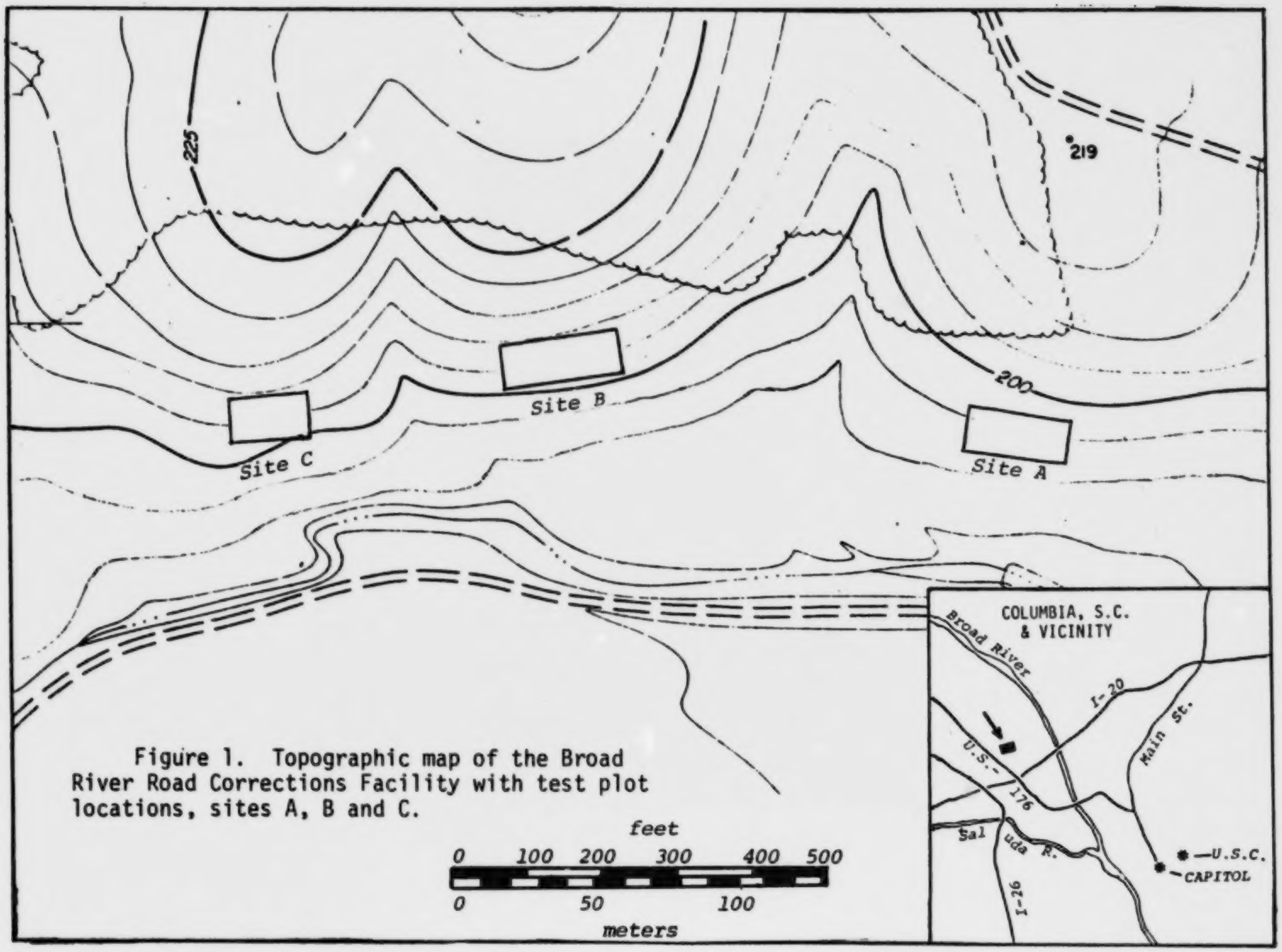
225
200
219
Site A
Site B
Site C
COLUMBIA, S.C.
& VICINITY
Broad River
I-20
Main St.
U.S.-176
Sal uda R.
I-26
U.S.C.
CAPITOL
feet
0 100 200 300 400 500
0 50 100
meters

Figure 1. Topographic map of the Broad River Road Corrections Facility with test plot locations, sites A, B and C.

Figure 2. The project site is located within the Broad River Road corrections facility. This photograph, taken in mid-April before groundbreaking, is a view from the center hillslope looking east.

SECTION 3

DESIGN AND INSTALLATION OF THE TEST FACILITY

The rate of soil loss and revegetation of drastically disturbed sites is a function of a complex interrelationship of independent parameters which include slope and soil characteristics, climate and precipitation. To assure a valid comparative test, variations between plots were to be minimized so that differences in measurements reflected variations in treatment effectivenesses. Subsequently, a parameter reflecting treatment effectiveness could be identified and monitored and the efficacy of the various treatments ascertained.

To minimize variations inherent to large areas, such as soil type variability, microclimatic effects and slope orientation, it was decided to apply the various treatments to small area plots located within one field site. In this manner, the soil response to each treatment could be simultaneously monitored on small, contiguous and similar runoff plots as a function of precipitation events. This technique permitted control of the variation among independent parameters and test of the effect that each erosion-revegetation treatment had on disturbed sites.

GRADING AND ESTABLISHING RUNOFF PLOTS

In preparation of the site for treatment application, all existing vegetation was removed and all slopes were adjusted to a common dip. The site was closely mowed with a standard bush hog and plowed to a depth of 5 inches (12.7 cm) with disc and chisel plows. This served to loosen the surface soil layers and provide an initial kill of the existing vegetation. Following a preliminary survey, specific portions of the hillsides which would afford the steepest slopes yet still maintain uniformity of testing conditions were identified among the three hillslopes. Rectangular sites that closely approximated the 12 to 15 per cent slope desired were staked off on each of the hillslopes. The sites were designed to be 120 feet (36.6 m) wide with a 30 foot (9.15 m) slope, striking North 85° East on the most easterly hillside; 150 feet (45.7 m) wide with a 30 foot slope (9.14 m) with a strike of North 60° East on the central hillside and 90 feet (27.43 m) wide with a 30 foot (9.14 m) slope striking North 70° East on the most westerly hillside.

Throughout all site areas, the slopes were initially formed with the use of a hi-way motograder to approximate the 13% desired slope. A drainage diversion ditch was dug along the top of the sites and 14-inch (35.5 cm) aluminum flashing was emplaced to fix the crest of slope. The area below the test plots was also shaped to accommodate the installation of a network to monitor and collect runoff (Figures 3a and 3b). During the grading process, approximately 0.5 to 1.5 feet (15 to 45 cm) of the topsoil, along with most of the remaining traces of previous vegetation, were removed from the sites. Following the grading, the ground was scarified to a depth of 5 inches (12.7 cm) and disc-plowed again to break up the clay rich subsoil.

After the ground at each site was prepared by the procedure described above, the sites were divided into plots 15 feet (4.57 m) wide using a 5-inch (12.7 cm) vinyl plot border product. Each of these plots, in turn, was subdivided into 10 feet (3.05 m) and 5 feet (1.52 m) portions by an additional piece of vinyl border, while maintaining a 30 feet (9.14 m) slope on each plot. When the installation was completed, each test plot had two portions, a 5 foot (1.52 m) and a 10 feet (3.05 m) width; each 30 feet (9.15 m) in slope length. The edges of the vinyl plot borders were buried at precisely the desired slope with a small border extending aboveground to prevent washover across plot boundaries. The plots were then rototilled to a depth of 5 inches (12.7 cm) (Figure 4). Using the vinyl plot border as a guide, the plots were hand raked several times until the ground surface was graded to precisely the desired slope (within a tolerance of 0.01 feet/10 feet; 0.1% grade). The hand rakings also served to remove the large quantity of pebble to cobble sized stones from each of the plots (Figures 4 and 5). Following this initial site preparation, a total of 24 test plots was prepared; 8 at Site A, 10 at Site B and 6 at Site C. At this point, each of the plots was ready for the installation of the sediment and runoff monitoring devices.

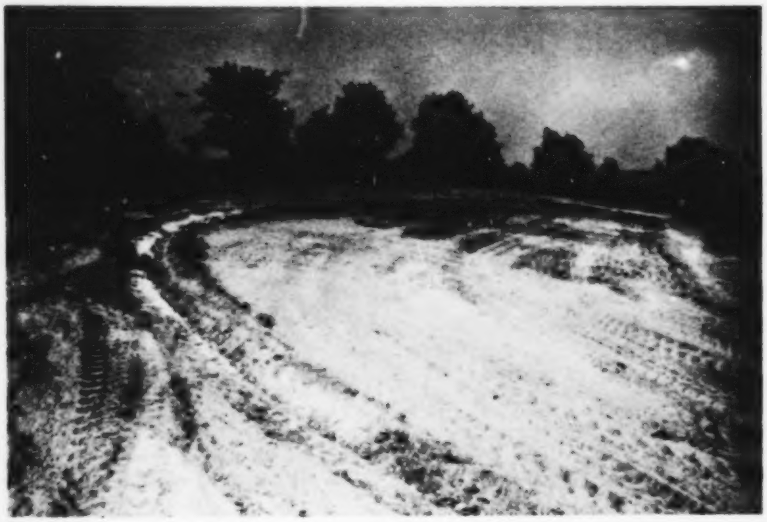

Figure 3a.

Figure 3b.

Figures 3a and 3b. Views of preliminary slope modification of test sites.

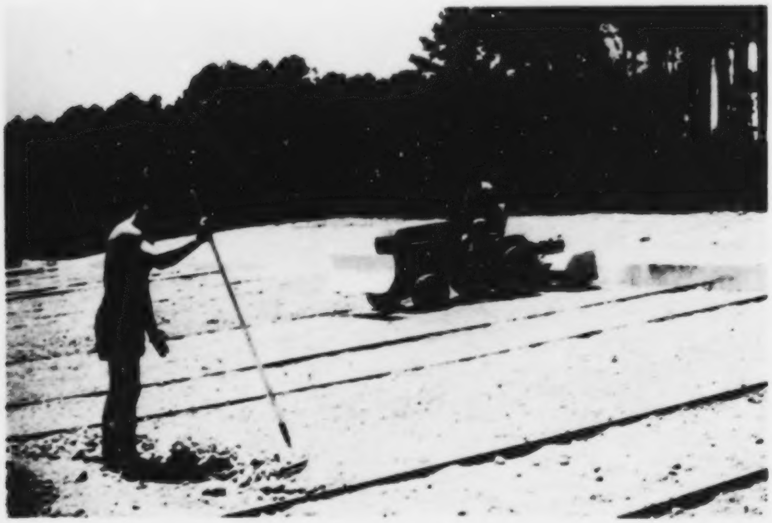

Figure 4. The vinyl borders, in addition to preventing washover across plot boundaries, serve to divide the sites into 15 feet (4.57 m) wide plots with 5 feet (1.52 m) and 10 feet (3.05 m) portions. The border was also used as a guide in hand raking the plots to the final grade. All plots were rototilled to a depth of 5 inches (12.7 cm).

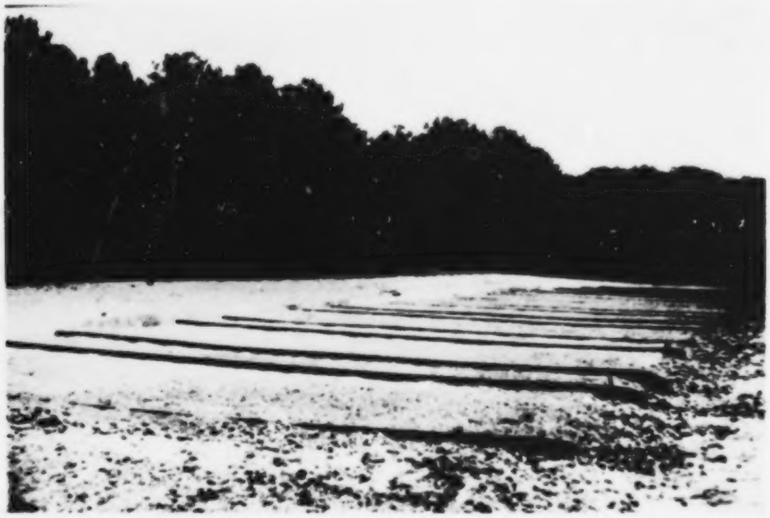

Figure 5. An overview of the center hillslope (Site B) with vinyl plot borders installed and final grading completed. At this site at this time, there are 10 test plots awaiting the installation of the monitoring network. Notice the gravel at the base of the plots, which was removed from the plots by raking.

DESIGN OF EROSION MONITORING SYSTEM

The sediment troughs to be used for the collection of surface runoff and eroded sediment were designed to be emplaced at the base of the 5 foot (1.52 m) wide portions of each test plot. The trough was fabricated to include a 6 inch (15.24 cm) apron which was fixed to the lip of the trough and buried at the base of the slope. In addition to gathering water and sediment, this lip also served to eliminate seepage at the soil-trough boundary. This was an added precaution in preventing runoff from bypassing the trough (Figures 6a and 6b). In addition, the partial burial of the lip portion of the trough minimized the erosion at the soil-trough interface. The trough had a volume of 2.5 cubic feet (0.0708 cubic meters) which encouraged settlement of coarse material in the trough. The overflow (i.e., when total runoff of the plot exceeded 2.5 cubic feet (0.0708 cubic meters) was forced to pass through a divisor plate containing 5 holes of equal diameter. The divisor plate served to separate the overflow into five equal volumes, allowing 1/5 of the total runoff from the plot to be collected in a 35-gallon (132 liter) drum downslope. Precise leveling of the plate after installation of the trough was afforded by having the plate fastened to the trough by adjustable screws (Figures 6a and 6b).

A 3.5-inch (8.9 cm) 24-hour rainfall event, which has a recurrence interval of 2 years in central South Carolina, will yield approximately 2 inches (5 cm) of runoff, as calculated from the S.C.S. (10,11), assuming average antecedent moisture conditions and a disturbed untreated soil surface. Application of treatments and the establishment of a vegetative cover should decrease the runoff coefficient and increase the capability of the collection system to collect all of the runoff. Based on these anticipations, the runoff collection system was capable of accommodating the flow produced by 2 inches (3 cm) of rain over the 150 square feet (13.94 m^2) plot, before the 35-gallon (132 l) barrel became full and overflowed.

A standpipe, the inlet of which could be rotated below water level, was built into the trough in order to drain the troughs of water during the time of sediment collection. To protect the material collected in the trough from debris and direct rainsplash, a cover was placed over the open portion of the trap (Figure 6b). A completed sediment and runoff collection system is shown in Figure 7.

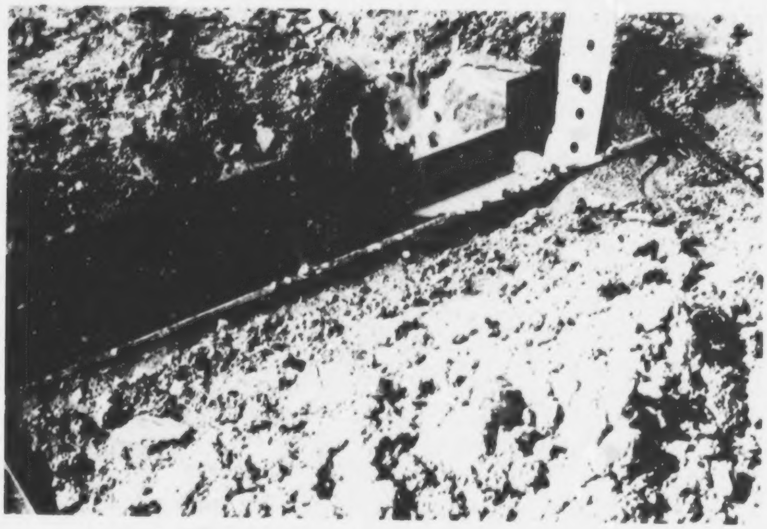

Figure 6a.

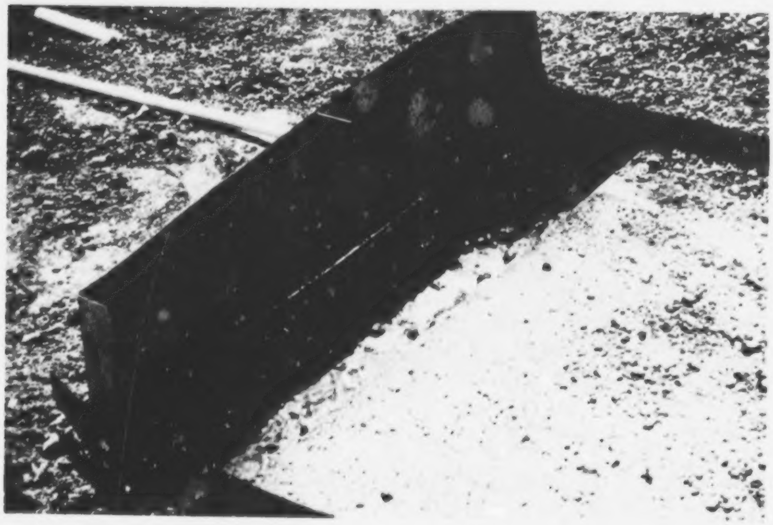

Figure 6b.

Figures 6a and 6b. The troughs illustrated were installed at the bottom of each plot. Notice the erosion due to flow under the trough (Figure 6a). Figure 6b shows the assembled trough with apron cover and divisor plate. The divisor diverts 1/5 of the overflow from the trough to a 35-gallon (132 l) drum downslope, via the 1½ inch (3.81 cm) pvc pipe which is connected to the center hole in the divisor plate. Installation of the apron eliminated seepage under the trough and assured that all of the runoff and sediment flows into the collector.

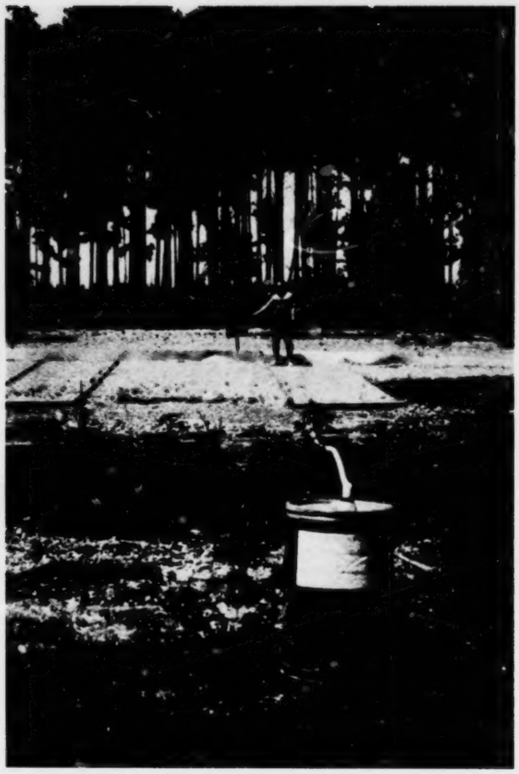

Figure 7. A complete erosion-runoff monitoring system.

TREATMENT FOR VOLUNTEER VEGETATION

A major problem that we encountered in the simulation of drastically disturbed soil conditions and which would radically affect the study results was the natural readvancement of volunteer vegtation. In a controlled sitution, the elimination of volunteer revegetation from the plots was critical in order to compare the effectiveness of each soil stabilizing treatment. During the tests, only that vegetation directly attributable to the soil treatment and stabilization process was considered in plot evaluation.

As outlined previously, 6 to 18 inches (15 to 46 cm) of soil were removed from the slopes during the grading process in order to expose the subsoil horizons and shape the hillside to the desired slope. This procedure did much to eliminate the remnants of vegetation; however, where the depth of excavation was limited to 6 inches (15 cm) some vegetation tended to reappear.

To correct this problem and surpress the volunteer vegetation, each of the 24 test plots was treated with Round Up, a contact herbicide, at an application rate of 2½ gallons (9.46 l) of a 1% solution per plot. The herbicide was sprayed evenly over each test plot whether or not vegetation was present (Figure 8).

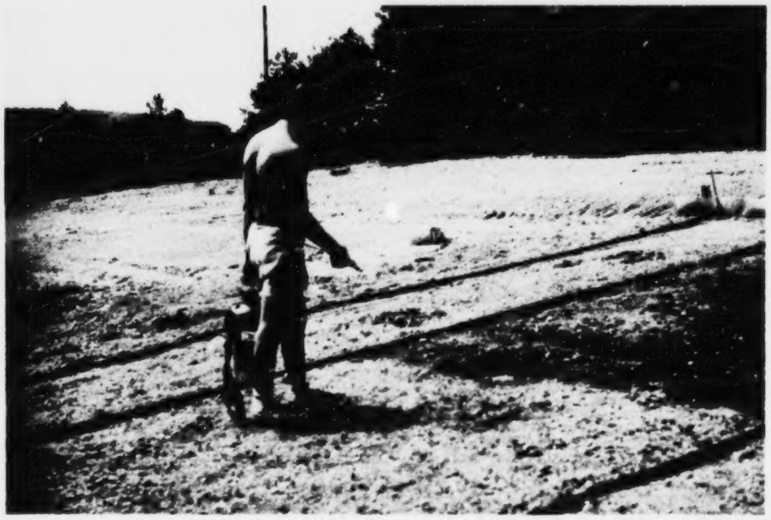

Figure 8. Two and one half (9.46 l) of a 1% solution of Round Up contact herbicide were applied to each test plot using a 3-gallon (11.35 l) capacity pump sprayer.

Upon contacting the leaves, the herbicide is absorbed by the plant and after 7 to 10 days the plant is killed. In the soil, however, the herbicide is readily dissipated and eventually degrades to innocuous levels. After the 10-day degradation period, a team of from two to five people covered each plot and removed all plant remnants by hand weeding and raking (Figure 9).

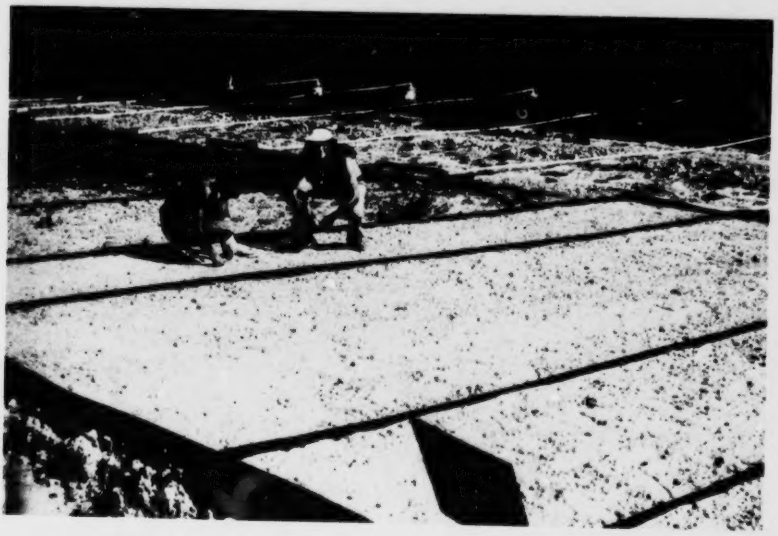

Figure 9. All traces of grass above ground as well as roots were removed by hand weeding and raking.

FERTILITY ANALYSIS

The variation in fertility between plots was tested by analyzing nine soil samples collected from a random grid pattern on each major hillside plot. The samples were analyzed by the Clemson Agricultural Extension Service and the results showed that the soil underlying the study site had low to average contents of phosphorus and potassium ((3 to 30 pounds/acre (0.53 to 5.5 kg/ha) phosphorus and 12 to 140 pounds/acre (2.2 to 25.7 kg/ha) potassium)). The calcium content was consistently low for all test plots ((100 to 400 pounds/acre (18.4 to 73.4 kg/ha)). Soil pH ranged from 4.6 to 5.3 and pH buffer from 6.40 to 7.25. Amendments of a 5-10-10 fertilizer at a rate of 500 pounds/acre (91.78 kg/ha) and agricultural limestone at a rate of 2,000 pounds/acre (367 kg/ha) was deemed sufficient to compensate for the variability in fertility and this mixture was applied to each plot during the treatment application.

SECTION 4

EROSION-REVEGETATION TREATMENTS

TREATMENTS, DESIGN AND ANALYSIS

Soil stabilizing and revegetation treatments have a two-fold purpose; first, short-term stabilization and protection of disturbed land and secondly, to create an environment for the rapid establishment of a natural vegetative cover. Most of the erosion treatments that were tested can be categorized into three major types:

(1) mulch treatments
(2) chemical stabilizers
(3) blanket products

Each of these categories and their functions in soil stabilization are described below.

Mulches

Mulch treatments serve mainly to absorb the erosive energy of rainfall impact, the primary mechanism for soil detachment, and to reduce sheetwash, the primary agent of transport (14). Mulches are also used and found effective in increasing infiltration, reducing runoff, replenishing deficient soil mositure and insulating the soil surface from extremes in temperature. Recent studies showed that the application of a mulch to a soil cover results in the generation of a more thermally moderate and moist environment at the soil surface, which encourages faster germination of seedlings (3,4).

Many materials have been used as mulches, including straw, hay, leaves, sawdust, wood shavings, manure, bagasse, paper scraps, cotton refuse and hardwood bark chips. At the present time, much work is being done in further developing and refining suitable hydromulches from wood and paper fibers and hardwood bark. Hydromulches are applied as a slurry with lime, fertilizer, seed, water and a tackifier (if used). A major advantage of hydromulches is their ease of application. Modern hydroseeders with capacities of 3,000 gallons (11,355.1) can apply mulches and treatments to cover more than 5 acres (2.02 hectares) in about 30 minutes.

Chemical Stabilizers

The composition of chemical stabilizers varies from an asphalt emulsion to a polymer latex or organic resin derived from plant gum or seaweed. Many of these products have an appearance and response similar to household glue. Chemical stabilizers are used as a soil binder in lieu of mulch treatments and as a tackifier in conjunction with mulch material. As a soil binder, these treatments coat and penetrate the soil surface, which increases the cohesion between soil particles. This surface bond not only reduces erosion by rainsplash and sheetwash, but also serves to retard dust and wind erosion as well. When used as a tackifier, these chemicals are employed to secure mulch material in place by securing contact points between mulch particles and between the mulch and the soil. In both methods of application, chemical stabilizers are also designed to reduce moisture loss from the surface soil layers (3,4).

Blanket Products

Blanket products are broad surfaced materials or nettings that are supplied in rolls and are applied in overlapping strips down the slope face and stapled to the ground with 6-inch (15 cm) pegs. Most blanket products consist of a type of netting that is interwoven with a mulch made of either paper, wood shavings or some other suitable material incorporated in the webbing. Blanket products afford the soil surface with all of the favorable attributes of a mulch treatment and, in addition, are more stable and difficult to disturb if properly installed. The blanket products, however, are more expensive to purchase and the method of application, requiring manpower to roll and staple the material, increases the total cost of installation.

TREATMENTS SELECTED FOR TESTING

Nineteen soil stabilizing and erosion control treatments were tested at the specially prepared field sites. The soil treatments included: Four hydromulches applied without a tacking agent, four netting products, eight chemical stabilizers applied with a small amount of wood fiber mulch and four of the stabilizers applied as tackifier on straw (Table 1). Of the chemical stabilizers used in this study, only one was an organic resin; the remainder were of the concentrated liquid polymer emulsion type.

On each of the three hillslope sites one plot was selected as an untreated standard to serve as a control and a basis of comparison. On these control plots, only the standard lime, fertilizer and seed mixture was applied. In addition, two plots were left in the disturbed state and were not treated in any way. The sediment yields derived from these control plots were used:

(1) to appraise the severity and degree of the erosion problem simulated in the test.
(2) as a baseline of comparison with which to ascertain the relative effectiveness of each of the treatments, and
(3) to check for variations in erosion rates among the three hillslopes that may be attributable to inherent variations in soil types, microclimatic environments and slope characteristics.

The study was designed so that the sediment yields derived from each plot could be used to assess the comparable effectiveness of similar products produced by different manufacturers as well as the relative efficacies of the different types of erosion control and revegetation treatments.

TABLE 1. LIST OF VARIOUS TREATMENTS MONITORED FOR EFFICIENCY OF EROSION CONTROL AND REVEGETATION ON DRASTICALLY DISTURBED SOIL SLOPES

Item #	Plot #	Treatment
		4 hydromulches
1	B-17	Conwed
2	A-6	Superior fiber
3	A-4	Silva fiber
4	B-12	Pulch*
		3 netting products presently available
5	A-1	Jute netting
6	B-9	Hold gro
7	A-5	Excelsior blanket
		8 tackifiers presently available, used as prescribed with a standard wood fiber mulch
8	B-10	Curasol AK and wood fiber mulch
9	B-18	Terra Tack III and wood fiber mulch
10	A-2	Aerospray (or DCA 70) and wood fiber mulch
11	C-20	Crust (500) and wood fiber mulch
12	C-22	Dow mulch binder and wood fiber mulch
13	A-3	Petroset SB and wood fiber mulch
14	B-13	Perma soil and wood fiber mulch
15	B-11	Genaqua and wood fiber mulch
		Straw mulch tested with 3 chemical stabilizers and 1 net stabilizer
16	A-7	Vexar plastic net over straw
17	C-21	Curasol AK and straw
18	C-19	Terra Tack II and straw
19	B-15	Dow mulch binder and straw
20	A-8	Untreated standard
21	B-14	Untreated standard
22	C-24	Untreated standard
23	B-16	Control
24	C-23	Control

*Effective January, 1978, this product, designated in this report as "Pulch", has been renamed by Rumose Products Company as "Spra-mulch".

APPLICATION OF TREATMENTS

In order to insure valid comparisons of the variety of materials and techniques, the application of the selected treatments to the respective test plots had to be done in accord with the application rates prescribed by the manufacturer. In addition, a reliable technique for application of each treatment to the test plots had to be assessed. The necessary information and guidelines for application were obtained from representatives of each product company. Requests were made for:

(1) a detailed price listing for a comparative cost analysis
(2) recommended application rates for the conditions at the test site
(3) necessary special instructions for dilution, mixing or application

Based on the data provided by the companies, the following guidelines for application rates were formulated.

Application Rates

Application rates for the selected treatments were needed which would suitably test the efficacy of each treatment while applying neither too much nor too little. At the same time, the rate selected should produce ranges of sediment yields between treatments that are sufficiently large so as not to be seriously affected by the small errors in sampling and data analysis. Further, by designing treatments in accord with optimum application rates, the cost of materials and application will be realistic and could be used to assess treatment efficiency as a cost-benefit analysis.

Rates of application were devised that considered both the cost per acre treated and the rates recommended by the manufacturers. The application rates chosen for testing are listed in Table 2. Also, each treatment was applied with standard lime, seed and fertilizer amendments in accord with the specifications listed in Table 3.

Application Technique

Hydroseeding--

Due to the relatively small size of the test plots (450 square feet; 41.8 m^2), a conventional hydroseeder with a 500 to 800 gallon (1,890 to 3,028 l) capacity and a fire hose-type nozzle capable of broad application patterns could not deliver the materials with the precision required for this study and was deemed impractical. Further, because of the residual that remains in the tank after each application, the amount of products that would be applied as a slurry would be very difficult to measure if the large hydroseeders were used.

To accommodate the needs and requirements of applying small volumes of treatments in precise manners, a precision laboratory hydroseeder was borrowed from the United States Department of Agriculture Forest Service at the Forest Products Marketing Laboratory, Princeton, West Virginia (Figure 10). This hydroseeder had an 8-gallon (30.28 l) capacity wedge-shaped chamber seated over a gasoline powered pump. The pump serves not only to drive the slurry through a fan-type nozzle, but to recirculate the slurry through the chamber to assure

TABLE 2. APPLICATION RATES OF MULCHES AND TACKIFIERS USED IN THIS STUDY

MULCH COMPARISON

1,200 lbs/acre ((220 kg/ha)(12.4 lbs/plot))

TACKIFIER COMPARISON

Liquid binders
50 gal/acre ((76 l/ha)(0.52 gal/plot))

Over either (1) wood fiber mulch at 500 lbs/acre ((91.78 kg/ha)(5.17 lbs/plot))
or (2) straw mulch at 3,000 lbs/acre ((550.7 kg/ha)(31 lbs/plot))

Solid binders
-Terra Tack II-
45 lbs/acre ((8.26 kg/ha)(0.47 lbs/plot))
Over straw mulch at 3,000 lbs/acre ((550.7 kg/ha)(31 lbs/plot))

-Terra Tack III-
40 lbs/acre ((7.34 kg/ha)(0.41 lbs/plot))
Over wood fiber mulch at 500 lbs/acre ((91.78 kg/ha)(5.17 lbs/plot))

TABLE 3. STANDARD SEED AND FERTILIZER APPLICATION RATES USED IN THIS STUDY

Seed Mixture	Per Acre	Per Hectare	Per Plot
Kentucky 31 fescue	50 lb.	9.18 kg.	0.52 lb.
Bermuda (Common)	15 lb.	2.75 kg.	0.16 lb.
Bahia (Pensacola)	15 lb.	2.75 kg.	0.16 lb.
Rye Grass (Annual)	10 lb.	1.84 kg.	0.10 lb.
Fertilizer (5-10-10)	500 lb.	91.78 kg.	5.17 lb.
Lime	2,000 lb.	367.1 kg.	20.66 lb.

mixing of the product and amendments and the uniform distribution of each in the slurry. In trials off the test area, we found that a 4 to 6 per cent solids slurry could be easily accommodated by the hydroseeder. However, before the treatment mixture could be recirculated, it was necessary to thoroughly hand mix the product for uniform response characteristics. Because of the high dilution rates and to insure correct application rates, each plot was treated with 3 to 6 loads of the hydroseeder. Each load was applied over equally subdivided plots with some overlapping to assure uniform dispersion of products. A plastic drop cloth was placed along the sides of the plot to prevent splash onto the adjacent plot and to insure that a treatment was confined to each plot (Figure 11).

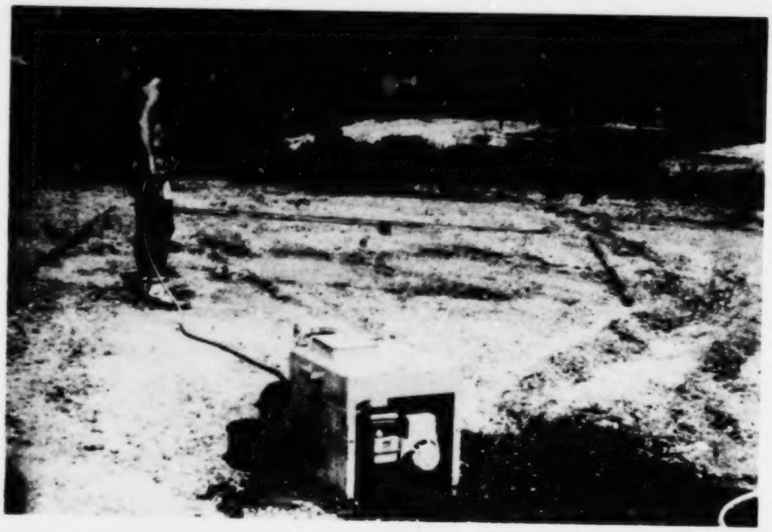

Figure 10. A Reinco laboratory scale hydroseeder was used for application of the treatments. It has an 8-gallon (30.28 l) wedge-shaped chamber over a gasoline powered pump used for propulsion and recirculation.

Figure 11. Applying hydromulch to a test plot in 4 applications of the hydroseeder. Notice the plastic drop cloth at the plot border to prevent splashover and contamination of the adjacent plot.

Straw and Blanket Products--

Application of straw and blanket products was done manually to insure an even distribution of material over the test plot. The lime, fertilizer and seed were applied using a drop seeder, which assured an equal distribution of material (as seen in Figure 12).

In the application of the blanket products, the material was rolled over the plot, overlapped and stapled as per directions (Figure 13). The straw mulch was dispersed by hand over the lime, seed and fertilizer. Subsequently, the tacking agents were applied over the straw, using the hydroseeder.

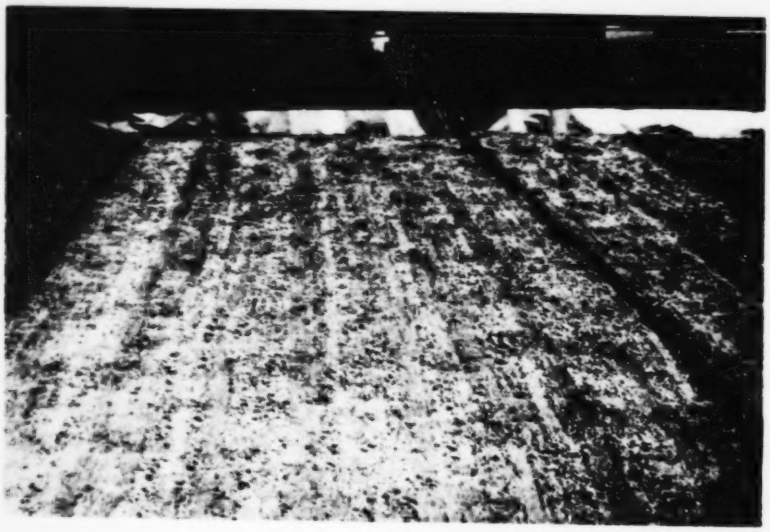

Figure 12. Lime and fertilizer were applied using a manual drop seeder to insure even distribution.

Figure 13. Application of excelsior blanket to the test plot on the standard lime, seed and fertilizer application.

SECTION 5

PHOTOGRAPHIC REPRESENTATION OF TREATMENT RESPONSE

INITIAL APPEARANCE AFTER APPLICATION (9/25/77 THROUGH 10/1/77)*

All treatments were applied during the six-day period from September 25, 1977, to October 1, 1977. Photographs of a representative group of the treatments at the time of application are shown in Figures 14 through 23. Figures 14, 15, and 16 show the three blanket products just after application. Care was taken during application to secure staples firmly to the ground to provide good ground coverage.

Figure 17 shows Plot A-7, which contained a straw mulch covered by a plastic net. It was found that hand dispersal of the straw mulch at a rate of 3,000 lbs/acre (550.7 kg/ha) was sufficient to achieve a good and even ground coverage. When the straw was tacked with Dow mulch binder and Curasol AK, there were distinct broken contact points between straw fibers when separated. This effect, however, was not found with the Terra Tack stabilizer. The Terra Tack product used in this study came as a powder with two components. It is possible that the two components were not sufficiently mixed in the laboratory scale hydroseeder, which prevented the full activitation of the components.

Plots A-4, B-17, and B-12 (Figures 18, 19, and 20) were treated with hydromulches. The wood and paper fiber hydromulches have a rich green color which at the time of application delineates and identifies the treated areas and is very useful during application when trying to achieve an even and complete coverage. As little as 30 hours later, however, the colors had been significantly bleached by the sun (Figure 19). The degree of uniformity of coverage afforded by a 1,200 lbs/acre (220.3 kg/ha) application rate of the tested hydromulches using the laboratory scale hydroseeder is evident in these figures.

Plots A-3 and C-20 (Figures 21 and 22) show only two of the tackifiers used which were tested at a rate of 45 gal/acre (68.8 l/ha) with 500 lbs (226.8 kg) of wood fiber mulch per acre (the initial appearances of all eight plots testing tackifiers were identical). When the ground dried after application of these treatments, only a faint yellow tinge betrayed the presence of the treatment. When dry, these tackifiers formed a crusty layer at the soil surface.

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*In some cases, the dates will be numerically depicted in order to facilitate photograph identification which incorporates a similar date format.

The three untreated plots were left in a slightly disturbed condition after application of the standard lime, fertilizer and seed mixture and a vigorous hand raking (Figure 23). In addition, two control plots were vigorously hand raked and received no treatment or seed of any kind.

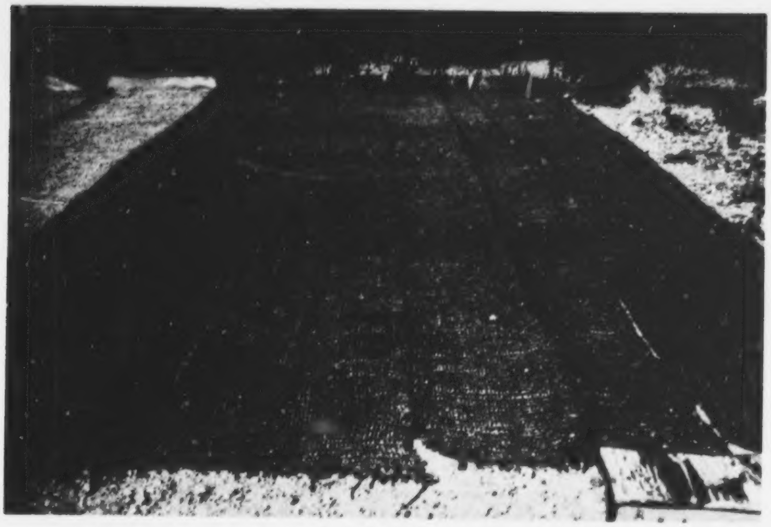


Figure 14. Plot A-1 on 9/25/77, following application of jute netting.

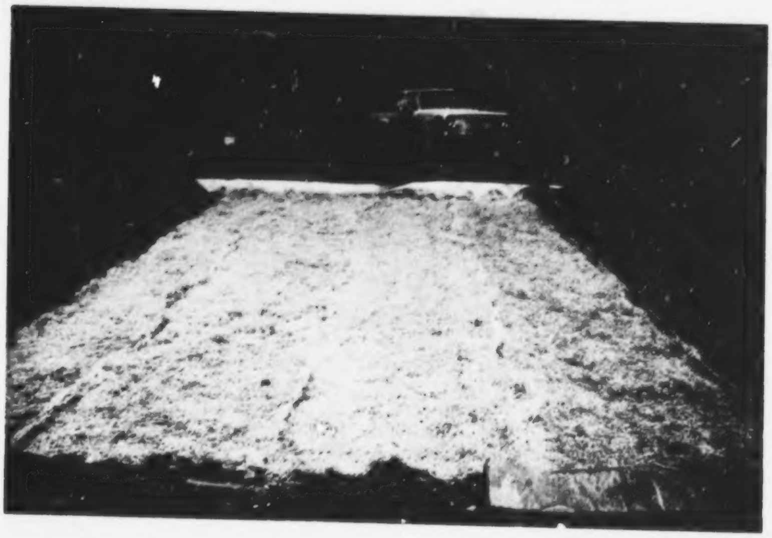


Figure 15. Plot A-5 on 9/25/77, following application of Excelsior blanket.

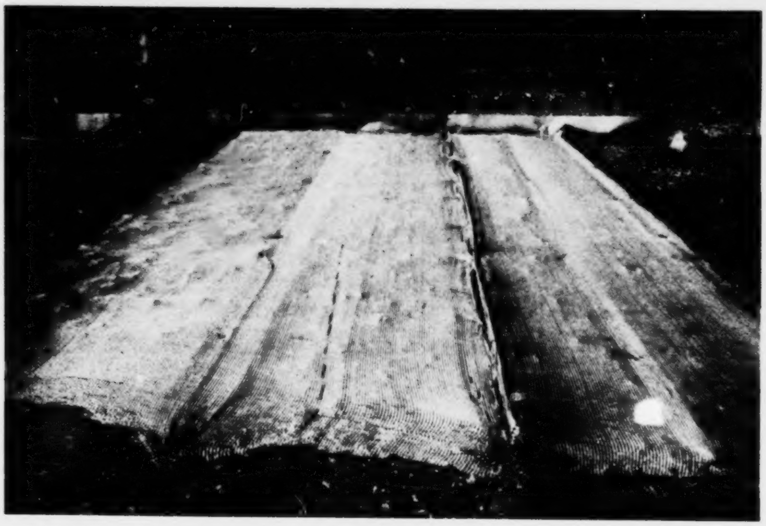


Figure 16. Plot B-9 on 9/25/77, following application of Hold gro erosion control fabric.

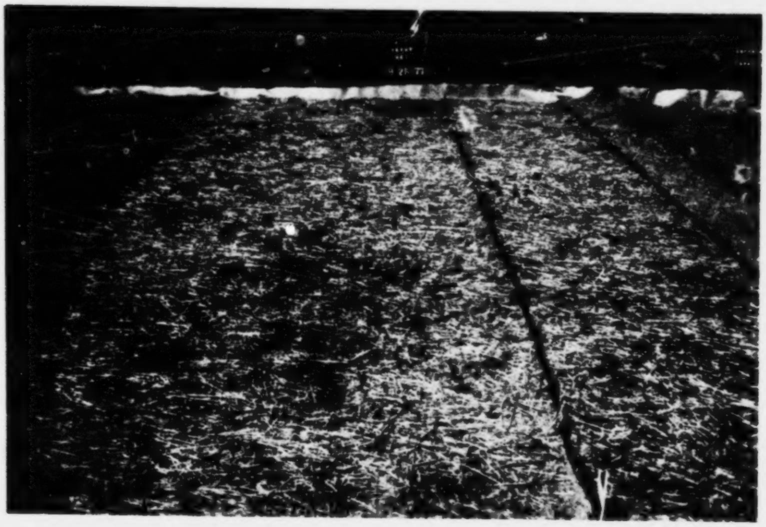


Figure 17. Plot A-7 on 9/25/77 following application of straw mulch and Vexar net.

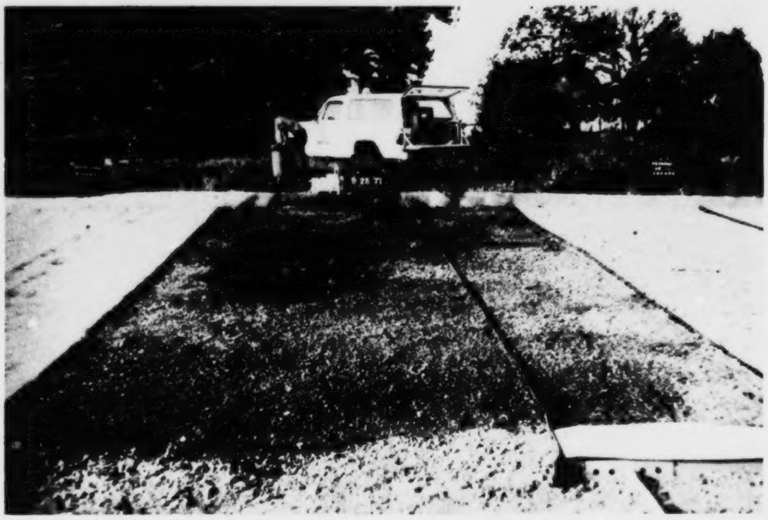


Figure 18. Plot A-4 following application of Silva wood fiber mulch.

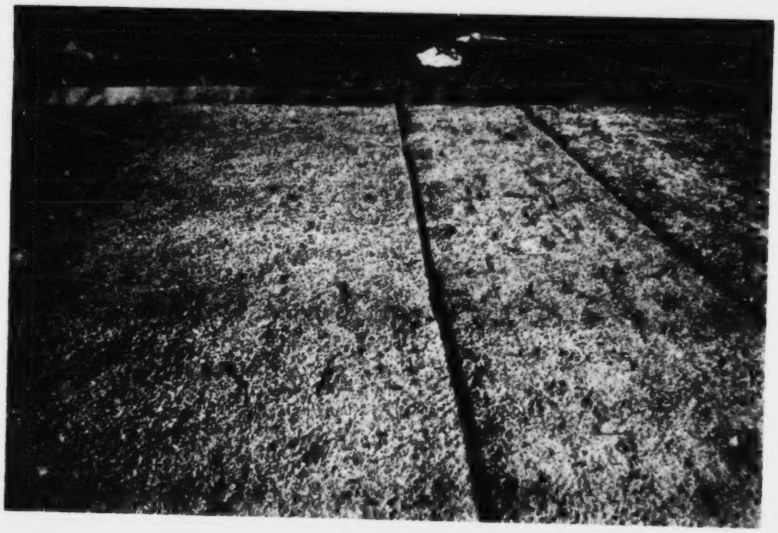


Figure 19. Plot B-17 following application of Conwed wood fiber mulch approximately 30 hours later after the sun had dried and bleached the mulch.

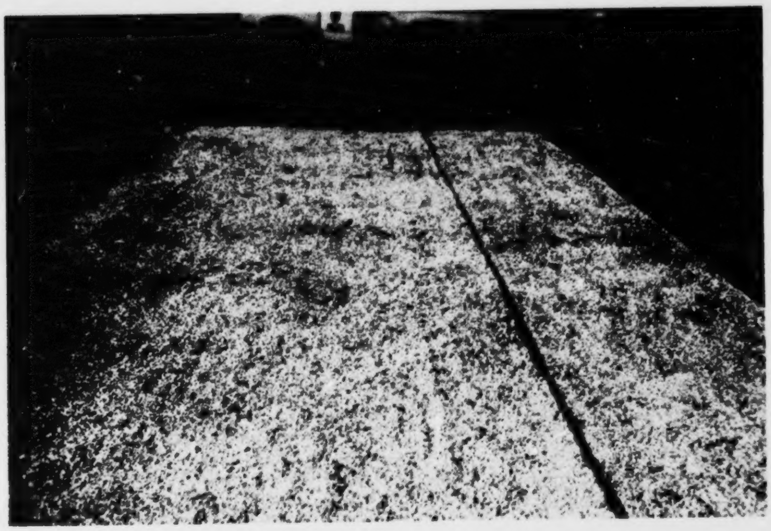


Figure 20. Plot B-12 following application of Pulch paper hydromulch.

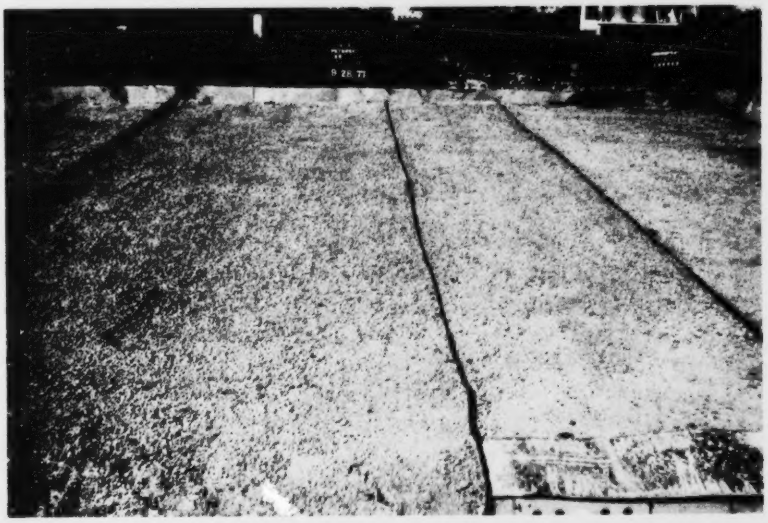


Figure 21. Plot A-3 following application of Petroset SB chemical stabilizer and wood fiber mulch at a rate of 500 lbs/acre (91.78 kg/ha). The treatment is extremely difficult to see after it dries.

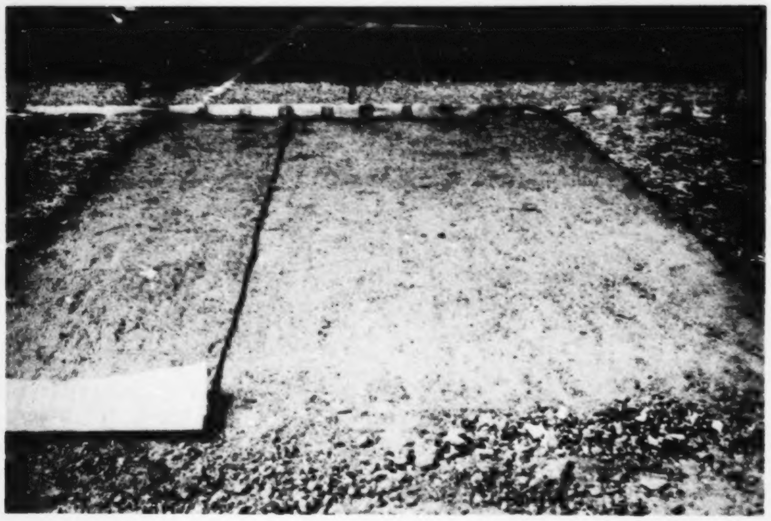


Figure 22. Plot C-20 following application of Crust 500 chemical stabilizer and wood fiber mulch at a rate of 500 lbs/acre (91.78 kg/ha). It is very difficult to see any trace of the treatment.

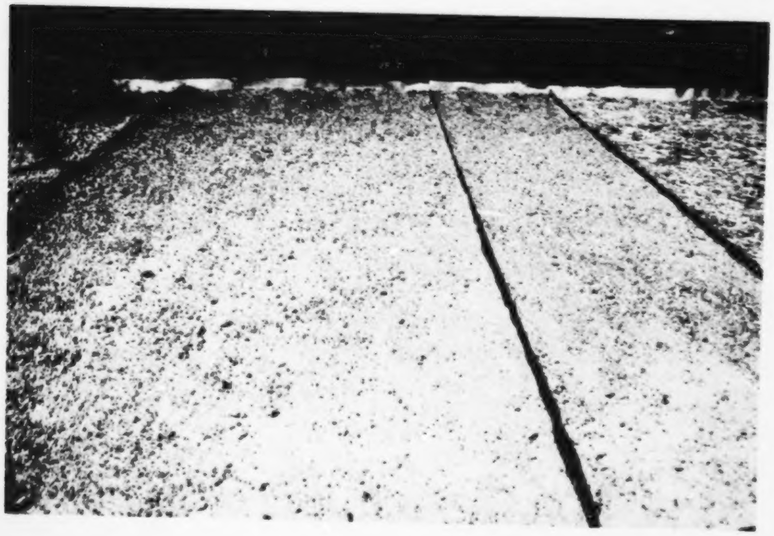


Figure 23. Plot A-8 is an untreated plot. Only the standard lime, fertilizer and seed mixture were applied to the untreated plots.

TREATMENT RESPONSE THROUGH 10/28/77

Although seedlings appeared on all plots two to three weeks after the application of treatments was completed, they appeared first, and with greater abundance, on the plots treated with straw and blanket products. This was probably due to the heavier ground cover afforded by the treatments which retained surface moisture to a greater degree during the periods between rainfall.

An unusually large amount of rain fell during the period between October 1 to October 28, 1977. During this time, it rained on eight days ((with a total precipitation of 4.83 inches)(12.27 cm)). The most significant storm was a 3.83 inch (9.73 cm) rainfall in 36 hours. It was during this period, just after application of the treatment and before establishment of a suitable vegetative cover, that the soil was most susceptible to erosion. During this time, the treatments were taxed to their limit in terms of protecting the soil from the erosive forces of wind and water and underwent their most rigorous test.

The photographic documentation of the response of the test plots during the entire test period is shown in Appendix A. In this graphic array, the plots are shown in order, plots A-1 through A-8 in Plates 1 through 8; B-9 through B-18 in Plates 9 through 18 and plots C-19 through C-24 in Plates 19 through 24. The photographs shown in each plate labeled a, b, c...depict the plots at different times during the test period.

Photographs on Plates 1a, 5a, and 9a show the plots that were used to test the three blanket products; jute, Excelsior blanket and Hold gro. The jute blanket (Plate 1a) was affected by shrinkage due to repeated wetting and drying from rain. This continous shrinking put a strain on the ground staples, which pulled apart and left gaps of exposed soil between strips. In these plots, the vegetative growth was found to be rather thin and concentrated only in low spots where seed and moisture may have accumulated. The Excelsior blanket (Plate 5a), in contrast, shows no obvious shrinking effects due to the rain and has a good stand of grass. The Hold gro blanket (Plate 9a) initially enhanced the start of a good vegetative cover, but through time this product tended to be lifted off the ground by the growing seedlings. Prior to the heavy downpour (3.83 inches in 36 hours) which occurred on the 25th and 26th of October, an estimated 30 to 40 per cent of the blanket area was held off the ground by the underlying grass. The intensity of the rain, however, drove parts of the blanket back to the ground. In spite of this beating down by the rain, small patches of this tenting effect were still visible after the rainfall event (Plate 9b).

The straw mulches in general showed the capability of initiating a good vegetative cover. No displacement of the straw mulch by the high rainfall intensity was discerned on any of the straw test plots, whether tacked by Vexar net (Plate 7a) or chemical stabilizer (Plates 15a, 19a, and 21a). The straw mulch tacked by Terra Tack II still showed no cemented contact points between straw fibers and the fact that this straw was not disturbed after the intensive rainfall of October 25 and October 26 indicates that the intertwining of straw fibers is sufficient in itself to stabilize the mulch on moderate slopes (such as in this test). Some volunteer growth of rye grass was derived from seedheads inherent in the straw mulch. This is intrinsic and is to be expected when using straw. This volunteer growth is detrimental only from an aesthetic standpoint when selective seeding is required for locations designed for special appearance or visual effect.

The results of the four hydromulches tested are shown in Plates 4a, 6a, 12a and 17a. The vegetative cover developed on these plots was relatively poor and was concentrated mostly in slight depressions where seed and moisture tended to collect. The hydromulches applied alone (with no tacking agent) did not adhere to the soil surface and were easily dislocated during the intense rainfall of the period in discussion. Agglomerations of the fiber mulches were found oriented transversely to the slope where the mulch had washed or rolled down the slope and collected on pebbles and small stones (Plates 4b and 17b). The Pulch paper mulch, in addition to the dislocations, was also washed out, with large amounts found 10 to 15 feet (3 to 5 m) beyond the plot.

The plots which tested the response of the 8 chemical stabilizers showed very poor development of vegetation during this period. Plates 2a and 2b show the Aerospray test plot. An inadvertent blockage in the drainage diversion ditch above the test plots caused water to spill over and erode a gulley through the demonstration portion of the test plot (fortunately, the sediment collection system was not affected). Upon closer inspection, a thin crusted layer 1/16 to 1/8 inch in thickness was observed to have formed where the tackifier had penetrated the soil, producing a hard surface layer resisting erosion. Similar crusting was found to have been developed in the other plots that were stabilized with tackifiers (as seen in Plates 3a, 20a, and 22a).

When the tacking agents were added to the mulches, there was a smaller downslope transport of the mulch. Some, however, still migrated to the base of the test plots (Plates 10a and 11a), and in some cases to a greater extent (Plate 13a).

The three plots that were seeded, limed and fertilized but untreated showed only traces of seed germination (Plates 8a, 14a and 24a). Erosion was most severe on the plots that showed the development of minor channelization of flow, which effectively increased erosion in several locations within that area.

TREATMENT RESPONSE FROM 10/28/77 THROUGH 11/28/77

During this one-month period, there was much less precipitation. The vegetation developed quite rapidly on the plots where straw treatments or blanket products had been applied. However, for the plots that were treated with mulch and chemical stabilizers, the vegetative cover was more sparse. This becomes especially apparent when comparing the plots treated with Aerospray (Plate 2b) and the Crust 500 (Plate 20b) chemical stabilizers with the more successful plots treated with either Hold gro (Plate 9c), Excelsior blanket (Plate 5b), or any of the straw mulches (Plates 7b, 15b, 19b or 21c).

During this period, development of the vegetative cover took place primarily through further growth of the small seedlings which had sprouted earlier. An absence of new germination was apparent. This was best documented by observations of the plots where sparse vegetation had matured, leaving large areas unprotected. In these cases, the seedlings grew bigger and, with the exception of taller stands of grass, no new ground cover developed.

TREATMENT RESPONSE FROM 11/28/77 THROUGH 12/15/77

During this 17-day period, very little precipitation took place, with total rainfall accumulation of 1.9 in. (4.83 cm) coinciding with the shortest observation period. The total vegetative cover development still follows the established trend of better cover for the plots treated with blanket products and straw treatments; however, the plots treated with mulch and chemical stabilizers showed increased vegetative cover through lateral rhizome development. During this period, the sparse vegetative cover spread laterally over the intervening bare areas and began to develop a more uniform blanket cover. This can be noticed especially for Aerospray (Plates 2b and 2c), Petroset (Plates 3b and 3c) and Genaqua 743 (Plates 11b and 11c).

TREATMENT RESPONSE FROM 12/15/77 THROUGH 1/23/78

During this 6-week period, the test plots received the largest accumulations and highest intensity rain of the entire period of investigation. The established vegetation continued to develop laterally, causing less and less variation in vegetative cover between the plots with varying treatment types.

During the latter part of this period, winter temperatures killed the established grass cover. With this consideration in mind, and with the fact that the period for observing the most sensitive differences in vegetative cover attributable to the treatments had passed, any further observations would be a reflection of the natural development of vegetation and not of treatment response. In addition, those plots that had a poor initial germination and contained sparse vegetation would be expected to produce additional vegetational growth due to lack of competition (in a relative sense) between plants already established. In contrast, the plots with a good grass cover would be expected to produce additional vegetative growth at a lesser rate due to competition of existing plants for food and moisture. Hence, through time the visual differences between each plot would become less apparent and eventually more uniform in cover. For these reasons, the visual assessment of plot response was terminated during the early part of 1978.

SECTION 6

SEDIMENT SAMPLING PROCEDURE AND ANALYSIS

SAMPLING

The sediment yield monitoring network was designed and installed to function with a minimum of maintenance. Sediment yields were monitored and measured after each rainfall event which was deemed to cause a significant and measurable amount of erosion. Following a rainfall event, a team would visit each plot and inspect the ground surface for a visual appraisal of the treatment's response to the rainfall. Appropriate field notes were made and annotated for inclusion in an evaluation of overall treatment response. In addition to the field inspection, the team also examined the sediment troughs and runoff barrels to see how much each had become filled with sediment. At a time when it was felt that the next storm event would overflow the collection chambers, the sediment yield from each plot was collected and measured by the following technique:

(1) the coarse sediment which had accumulated in the trough was scraped from the trap and collected in a sample bucket (Figures 24a and 24b).

(2) the runoff containing the fine grained sediment and which accumulated in the barrel positioned downslope of the trap was agitated and a depth integrated sample of at least 12 fluid ounces (300 ml) was collected.

(3) the depth of water collected in the barrel was measured by a dip stick to determine the volume of water.

(4) the barrel was emptied and the monitoring network reassembled in preparation for the collection of sediment yield of the next rainfall event.

LABORATORY ANALYSIS

The coarse sample fraction collected from the trough was dried and weighed in the laboratory (Figure 25). The dip samples collected from the barrels were analyzed for suspended solids using the standard United States Geological Survey method outlined in T.W.R.I. (7). Basically, an aliquot of sample was filtered through a preweighed 0.45μ Millipore filter. The filter was then dried and weighed to measure the weight of suspended material that was filtered from the aliquot of sample. By noting the volume of water contained in the barrel, the weight of sediment filtered from a volume of water could be easily translated to yeild of fine grained sediment produced by each plot in response to a particular rainfall event.

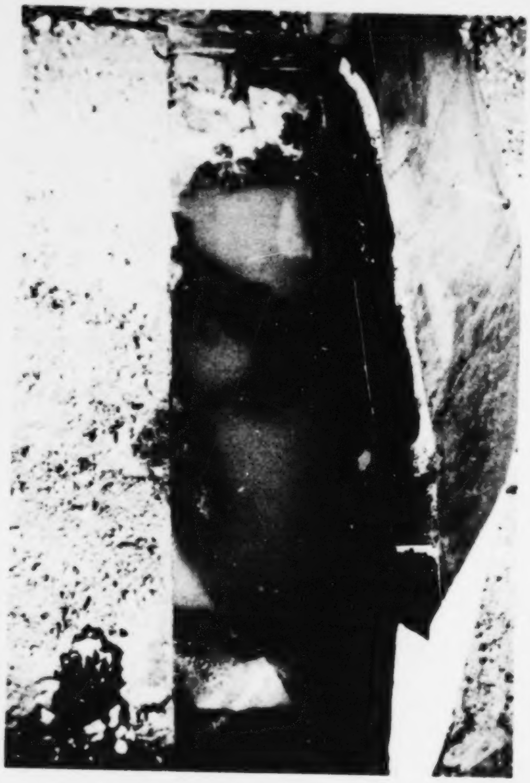


Figure 24a.

Figure 24b.

Figures 24a and 24b. Water is drained from the trough by gradually lowering the standpipe (a). The sediment is then scraped from the trough and collected (b).

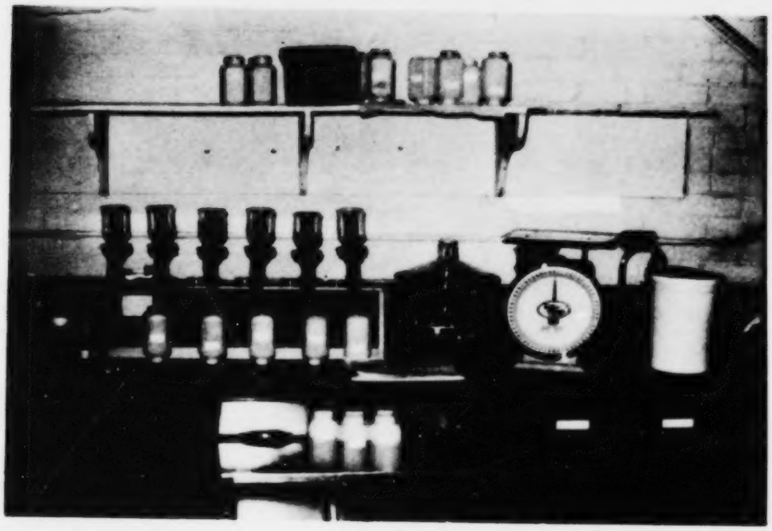


Figure 25. The laboratory was equipped for analysis of suspended sediment samples with Millipore filtering apparatus. The laboratory was also equipped with a large oven and large laboratory scales for measuring dry weight of coarse sediment scraped from traps.

SECTION 7

SEDIMENT YIELD DATA

SEDIMENT YIELD COMPARISON

As discussed previously, the frequency and interval of sediment sampling was dictated by the frequency and duration of rainfall. The plots were continually inspected during the field visits and the sediment collection troughs were routinely examined to determine if a measurable amount of sediment had accumulated in the traps. When a sufficient volume of sediment had accumulated, a collection phase was planned.

During the initial part of the study and immediately following application of the treatments, the soil surface was at the most disturbed condition and only the protective and/or bonding effects of the treatments protected the soil surface from erosion. Consequently, it was during this critical time that each soil erosion treatment was subjected to its most severe test. Accordingly, the sediment yield data gathered during the first several months reflects best the efficacy of the treatment in preventing surface soil erosion. As outlined in the first part of this report, the soil treatments are designed to afford the soil with a protective coating while at the same time providing a suitable environment for vegetation germination and growth. Initially, the treatments afford maximum protection. Through time, however, the vegetational cover eventually takes over and provides the ground cover for perpetual soil stabilization. In some cases, the vegetational development is accompanied by soil amelioration or mulch deterioration (in the products which will degrade with time).

The initial collection phases described below were made during the time predating the full establishment of vegetation and reflect conditions under which the soil was stabilized only by the treatment. Although some germination and vegetational growth had occurred during this period, the interfingering root network had not yet developed and, for all intents and purposes, did not afford the soil surface with a fully protective cover.

The first sediment sample collection was performed on October 27, 1977, approximately 4 weeks after application. A total of 4.83 inches (12.27 cm) of rainfall had fallen during the period, including a high intensity of 3.83 (9.73 cm) in a 36-hour period on October 25 and 26. (Figure 26). The sediment yields for this period are summarized in Table 4. As can be seen, erosion from the untreated (U) and untouched control plots (X) were rather significant, with yields ranging from 3.25 to over 4.0 tons/acre (1,191 to 1,466 kg/ha) for the period. When projected to annual sediment yields, these quantities seemingly represent sizable sediment losses. However, it must be kept in mind that this

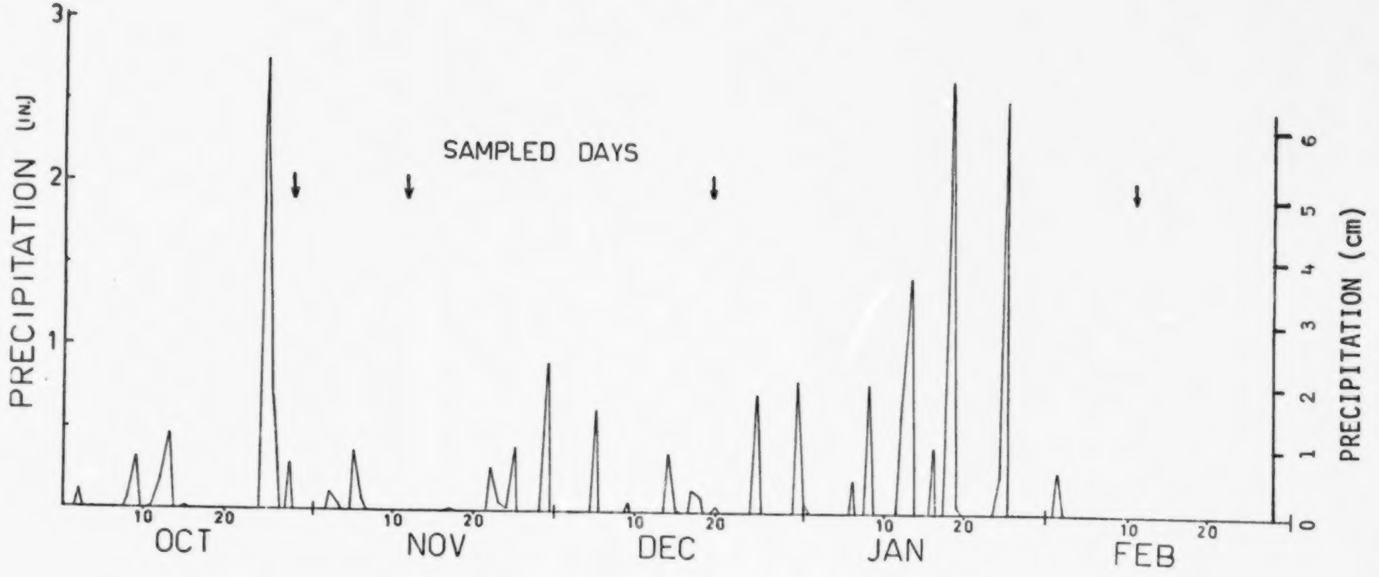


Figure 26. Rainfall intensity and distribution occurring in area of test plots. Days during which sediment samples were collected are also indicated.

sediment yield was derived from the plots during a 27-day period, with the vast majority of erosion and sediment yield taking place during the two days of high intensity rainfall.

A number of treatments were very successful in limiting the amount of erosion. The blanket products (code B), as well as the straw treatments (S), were shown to be quite effective in preventing soil erosion. Also, plots treated with several chemical stabilizer treatments showed good results. While some plots treated with chemical stabilizers did relatively poorly; with sediment yields ranging from 0.8 to over 2.2 tons/acre (293 to 806 kg/ha). The plots treated with hydromulches had sediment yields around 0.9 tons/acre (329.9 kg/ha) with one anomalously bad reading. In these high sediment yield cases, hydromulches were used with no tacking agents (Table 4).

Following a heavy rain, a large amount of the untacked mulches were found to have been washed from the plots and collected in the sediment traps. This was the most obvious deficiency for the paper confetti hydromulch used in this study. The wood and paper fiber hydromulches were also found in large quantities in the traps and distinct evidence of the downslope movement of these mulches was found in the transverse ribs of mulch that were formed against pebbles and ground irregularities (as discussed in the previous section). Based on these observations, it is recommended that hydromulches be used in conjunction with a tackifier to obtain maximum slope protection and stability.

The next sediment collection was performed on November 11, 1977, only two weeks later. Precipitation during this period totalled only 0.84 inches (2.13 cm), with 0.27 inches (0.69 cm) falling on October 28 and 0.36 inches (0.91 cm) on November 5 (Figure 26). The sediment yields for this period (Table 4) are at least an order of magnitude lower than the previous sampling period. Although this is in part attributable to the lesser amount of rainfall and lower intensities, sediment yields were expected to reduce drastically due to a depletion in the amount of soil readily available to erosion as the surface became compacted and reworked by rainfall. In addition, the stabilizing effects of the establishment of vegetation were becoming more apparent. By this time, a substantial grass cover had developed on the straw and blanket product plots, and the mulch and tackifier test plots had begun to show a much more even distribution of young seedlings than was apparent on October 28, 1977.

Although the total sediment yields were much lower than the previous sampling period, the relative sediment yields from each plot showed the same proportions. The treatments which had the least stabilizing effects during the initial sampling period continued to show the highest sediment yields.

Sediment samples were again collected on December 19, 1977. The total precipitation for the period from November 11 through December 19 was 2.60 inches (6.6 cm) with the majority of the rain falling on November 29 ((0.90 inches)(2.29 cm)) and December 5 (((0.63 inches)(1.6 cm)(Figure 26))). In spite of increased rainfall, the total sediment yields for this period (Table 4) were yet still lower, most probably due to the advancing and continued growth progress of the revegetation. There is a noticeable decrease in the variation of sediment yields for this sampling period, which may be due to the

TABLE 4. SEDIMENT YIELD DATA FOR ALL PLOTS

CODE	PLOT	SEDIMENT YIELD (TONS/ACRE)* 10/27/77	11/11/77	12/19/77	2/10/78	TOTAL YIELD (TONS/ACRE)*	VM FACTOR**
B	A-1	0.388	0.028	0.016	0.023	0.455	0.110
B	A-5	0.302	0.016	0.008	0.032	0.358	0.086
B	B-9	0.524	0.022	0.020	0.071	0.637	0.147
T	A-2	0.953	0.103	0.098	0.403	1.557	0.378
T	A-3	1.095	0.120	0.075	0.200	1.490	0.361
T	B-10	0.318	0.030	0.036	0.126	0.510	0.118
T	B-11	0.238	0.022	0.013	0.065	0.338	0.078
T	B-13	1.479	0.071	0.048	0.053	1.651	0.381
T	B-18	2.261	0.144	0.091	0.129	2.625	0.607
T	C-20	0.992	0.076	0.056	0.294	1.418	0.226
T	C-22	0.806	0.061	0.056	0.243	1.166	0.185
M	A-4	0.897	0.066	0.040	0.095	1.098	0.266
M	A-6	2.376	0.239	0.087	0.182	2.884	0.699
M	B-12	0.979	0.054	0.046	0.132	1.211	0.280
M	B-17	0.814	0.049	0.040	0.115	1.018	0.235
S	A-7	0.375	0.020	0.011	0.050	0.456	0.110
S	B-15	0.057	0.004	0.007	0.023	0.091	0.021
S	C-19	0.567	0.025	0.016	0.070	0.678	0.108
S	C-21	0.514	0.029	0.022	0.059	0.624	0.099
U	A-8	3.468	0.270	0.127	0.257	4.122	0.999
U	B-14	3.252	0.185	0.093	0.088	3.618	0.877
U	C-24	3.745	0.321	0.872	-	4.938	0.785
X	B-16	3.516	0.180	0.133	0.500	4.329	1.000
X	C-23	4.038	0.309	0.664	1.276	6.287	1.000

CODE: B-blanket products; T-tackifiers; M-hydromulches; S-straw; U-untreated, but seeded with lime and fertilizer; X-no treatment or seed (untouched).

PLOT: Letter signifies hillslope and number, plot.

*To obtain kilograms/hectare, multiply these values by 366.5.

**VM factor is the ratio of sediment yield from the test plot to the sediment yield from the control plot; the lower the ratio, the more effective the treatment. X(A); the yield of sediment from the control plot A was estimated from Figure 27 to be 4.124 tons/acre.

lateral development of the grasses in the initially poor test plots, as noted previously.

Precipitation increased drastically in the following weeks, with several events of high intensity and significant accumulations, including two storms with 2.5 inches (6.35 cm) of precipitation. Total rainfall for the 8-week period was 9.14 inches (23.22 cm) and the new sample collection was done on February 10, 1978. By this time, however, revegetation had become well established and the more successful treatments had produced a formidable vegetative protection for the soil. Sediment yields were only slightly higher than the previous sampling period which had a much lower rainfall and erosion potential. The data from samples collected on February 10 also show much lower sediment yields than the first sampling period which also had a lower rainfall erosion potential. The lower sediment yield with time is due to a decline in the availability of sediment as compaction of the soil takes place and the winnowing out of fines, leaving a coarse layer, which armors the surface. This can best be exemplified by comparing the control plots (X); B-16 and C-23 for the first (10/27/77) and last (2/10/78) sampling periods (Table 4). Note, however, that the trends in sediment yield (reflecting the efficacy of the various types of treatments) continue to retain similar patterns with time. Consistently, the plots with the straw and blanket products had the lowest sediment yields and the plots treated with mulches and tackifiers were progressively less successful. These trends support the contention that treatments which are initially effective in reducing erosion are also more effective in establishing a lush vegetative cover and permanent soil stabilization.

Soil conservationists now employ a new parameter in the Universal soil loss equation, the VM factor (13). The VM factor represents a vegetative or maintenance erosion control practice and is a total soil loss ratio expressed as a decimal. Values range from 0.0 to 1.0, where a value of 0.0 means the erosion control practice has eliminated all erosion and a VM factor of 1.0 means the practice has done nothing to reduce the erosion from that of a drastically disturbed condition.

To compare the effectiveness of treatments, all total sediment yields shown in Table 4 were converted to a VM factor. This factor is calculated as the ratio of the sediment yield of the test plot to the sediment yield for the untreated and untouched control plot (coded X) on that hillslope. These conversions served to filter out the minor variations in soil, insulation or weathering conditions among the hillslope test sites. In addition, the VM factors could be used to facilitate comparisons of treatment effectiveness among the test plots and compare the results of this study to other similar investigations performed under different soil and climatic conditions (discussed in a later section.

To discern variations in sediment yield from each hillside, the total sediment yields derived from each treatment were plotted with respect to the hillslope on which that test plot was located (Figure 27). The plots treated with blanket (B) and straw (S) products still show the best results. The plots treated with hydromulches (M) produced more sediment than most of the plots treated with chemical stabilizers (T). When compared to the untreated (U) and

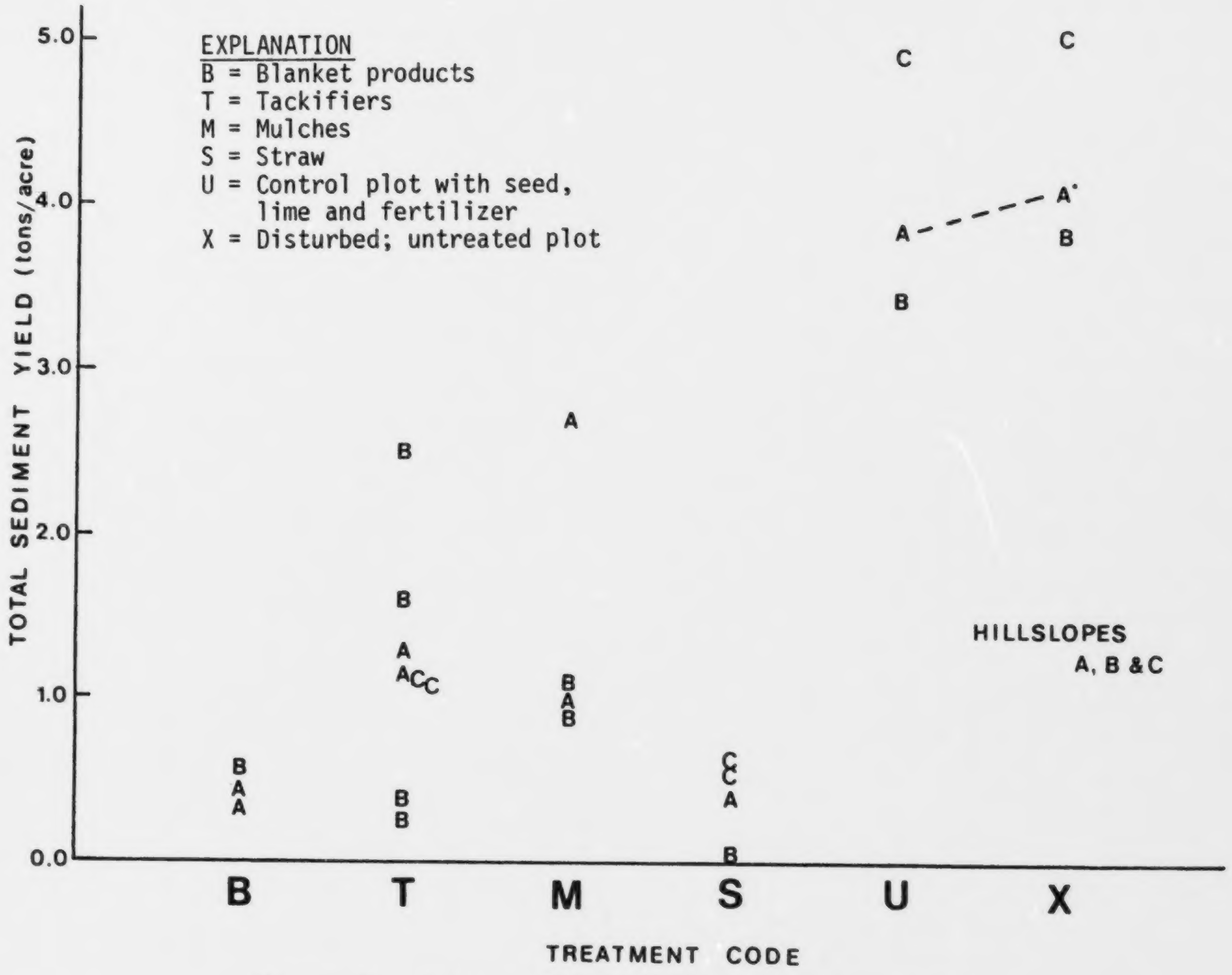


Figure 27. Sediment Yields Grouped by Treatment Types

control plots (X), however, all treatments had some beneficial effect in stabilizing the soil.

An evaluation of the sediment yields for the untreated and control plots (Table 4 and Figure 27) derived from the three hillslopes shows a consistent variation that reflects a heterogeneity of soil types underlying the three sites. Soil losses from the plots located on the C hillslopes were consistently greater than those on the A and B hillslopes. This was due to the higher clay content soil underlying the C hillslope and was reflected by an increase in soil erosion and sediment yield. During a field inspection, we noted that the attempts to revegetate the untreated test plot at hillslope C were not successful. It appeared that following a rain, most of the seed had washed away and that little, if any, ground stabilization had taken place. However, for the treated plots very little, if any, difference in sediment yields is discernible for similar treatments on the A and B hillslopes (Figure 27). This similarity in sediment yields shows that the treatments were effective in stabilizing the fine grained component of the soil horizons and retaining this portion on-site.

TREATMENT EFFICIENCY AS A FUNCTION OF GRAIN SIZE

Due to the nature of the monitoring facilities, all sediment collected in the runoff barrel downslope was segregated from the coarse fraction by a mechanism common to each plot. Consequently, the concentration of fine sediment found in each of the runoff barrels provided a relative assessment of the efficiency of the treatments in protecting the fine grained fraction of the soil.

Table 5 shows the concentration of fine sediment derived from each plot as it was collected in the runoff barrels. The trend in the fine grain sediment yields collected from each plot decreases significantly with time as the vegetation forms a protection for the soil surface. The fine grain sediment collected on October 27, however, was derived from plots that did not yet have the fully developed vegetational cover and were protected only by the treatment that was applied. In essence, then, the data summarized in Table 5 reflect the treatments' ability to protect the fine soil fraction and provide a good indication of the relative soil stabilization efficiencies of each.

As would be expected, runoff from the untreated and control plots (U and X) had high concentrations of suspended material, with the control plots located on hillside C having the highest; most likely attributable to the higher clay content of the soil found at this location (discussed in previous section). Several of the plots treated with tackifiers, including Curasol AK (B-10) and Genaqua (B-11) yielded low concentrations of fine grained material. The Crust 500 (C-20) and Dow (C-22) treated plots also yield low concentrations when considering the plot locations to be on the C hillslope and in a slightly finer material. The Terra Tack (B-18) did not afford good protection and the plot with this treatment yielded a very high concentration of fine grain material. As indicated previously, the Terra Tack was not properly agitated in the hydroseeder and quite probably the necessary mixing required to form a bonding material did not take place. Notice that the straw treatment tacked with Dow mulch binder (B-15) produced the lowest recorded fine grained sediment concentration, yet the straw tacked with Terra Tack (C-19) produced much higher con-

TABLE 5. FINE GRAIN SEDIMENT YIELDS OF TEST PLOTS FOR EACH SAMPLING PERIOD

		FINE SEDIMENT CONCENTRATION (ppm)				
CODE	PLOT	10/27	11/11	12/2	12/19	1/23
B	A-1	2,618	362	78	98	150
B	A-5	2,750	252	57	137	286
B	B-9	3,351	1,314	CLEAR	116	178
T	A-2	2,291	1,041	235	250	1,189
T	A-3	3,520	1,169	469	482	956
T	B-10	778	197	645	48	210
T	B-11	739	444	130	67	225
T	B-13	3,123	606	502	545	109
T	B-18	6,094	1,096	231	635	413
T	C-20	1,764	648	156	315	1,267
T	C-22	1,520	833	152	257	1,202
M	A-4	3,433	---	348	136	681
M	A-6	7,817	6,899	519	244	1,183
M	B-12	3,164	---	---	80	120
M	B-17	1,182	410	---	280	204
S	A-7	4,723	425	116	163	210
S	B-15	225	CLEAR	CLEAR	CLEAR	114
S	C-19	2,255	514	67	80	523
S	C-21	---	638	92	76	186
U	A-8	5,591	1,932	1,158	434	810
U	B-14	2,251	1,190	931	1,004	170
U	C-24	6,522	4,246	---	3,520	4,238
X	B-16	5,730	---	723	422	841
X	C-23	6,371	---	3,036	3,096	---

CODE: B-blanket products; T-chemical stabilizers and tackifiers; M-hydromulches; S-straw products; U-untreated (application of standard lime, fertilizer and seed mix only); and X-untreated.

centrations. Straw tacked with a netting (A-7) yielded fine grain concentrations comparable to the untreated plots.

The plot treated with mulches gave varying results. Conwed wood fiber mulch (B-17) produced a low fine grain sediment concentration, while the plot treated with Superior Turfiber ((A-6)(cardboard fiber)) produced the highest recorded fine grained sediment concentration. The plots covered with blanket products produced average to high concentrations of suspended material.

Due to the wide range of values and the expected natural variations in minor grain size distribution from site to site, coupled with differences in runoff rates, conclusions based on the suspended sediment data are, at the most, tenuous. It appears, however, that some chemical stabilizers did succeed in binding the fine soil particles and, to some extent, were effective in significantly reducing the erosion of the fine fraction component of the soil.

SECTION 8

COST BENEFIT ANALYSIS

Maximum effectiveness of soil stabilization is a primary concern when choosing an erosion control treatment for a specific problem area. However, the reclamation effort must be economically feasible as well as environmentally sound. In cases such as strip mines, sand and gravel pits and large construction sites, the areas to be reclaimed may be on the order of hundreds of acres, and the cost-benefit ratio becomes a necessary consideration in deciding upon a particular treatment application.

The costs for implementing various erosion control-revegetation treatments can be broken down into two major categories; cost of materials and installation costs. Costs for materials are listed in Table 6, prorated by application rates used in the test. It is very difficult, however, to calculate a reliable estimate for application of such treatments, with such variables coming into play as a crew's experience with a product, labor rates, site location, time and season of application and the size of the job. It is expected, though, that treatments that can be applied with the greatest ease will, in a sense, be the least expensive to employ. With this in mind, a relative degree of difficulty in treatment application is reflected in Table 6. An "A" listing signifies the easiest and probably most inexpensive application technique. As an example, seed, fertilizer and treatment can be applied in a slurry in one application with a hydroseeder. This reduces the time spent on the site as well as application time. The hydromulches also have the lower cost for materials. However, the chemical stabilizers with mulches cost approximately double, due to the slightly higher per acre cost for the material itself as well as the additional cost of the added wood fiber mulch.

The straw treatments were given a "B" rating for expense in application, due to the additional step required to blow the straw onto the site. Although the straw mulch costs only $120 per acre ($48.50 per hectare), an additional cost is incurred by the application of the tackifier over the straw. In the case of the straw tacked with Vexar net, there is an even larger cost increase, due to the labor required to manually apply the netting product and the cost of the net and staples. All of the blanket products reflect this increase in labor for manual application and stapling and so were all given a "C" rating. The costs for these materials were much more expensive than any other treatments.

By considering the effectiveness of these products with respect to the expense for treatment, an analysis of the most advantageous treatment for specific conditions can be discerned. The blanket treatments are the most effective in controlling erosion and have a much greater stability due to the staple

TABLE 6. COST ANALYSIS ON PER ACRE BASIS*

Product Tested	Total Cost Materials (per acre)**	Relative Expenses for Application***
Blanket		
Excelsior	$1,597	C
Hold gro	$2,129	C
Jute	$1,228	C
Hydromulches		
Conwed	$120	A
Silva	$111	A
Turfiber	$115	A
Pulch	$84	A
Chemical Stabilizers (with 500 lbs/acre at $50)		
Curasol AK	$225	A
Genaqua 743	$220	A
Aerospray 70	$242	A
Dow Mulch Binder	$157	A
Petroset SB	$200	A
Terra Tack III	$166	A
Straw with Tackifiers (Straw at 3,000 lbs/acre at $120)		
Straw (Vexar net)	$604	C
Straw (Curasol AK)	$295	B
Straw (Terra Tack II)	$231	B
Straw (Dow Mulch Binder)	$227	B

*Based on 1977 price quotations.

**To obtain cost per hectare, multiply these values by 0.404.

***Expense for application is presented as a relative degree of difficulty in installing treatment. "A" requires the easiest technique for application, where lime, seed, fertilizer and treatment are installed with the hydroseeder. "B" requires the additional step of blowing the straw, and "C" requires very involved manual application of the treatment.

method of tacking. Yet the expense makes utilization on a large-scale basis uneconomical. Under such circumstances, these blanket products could be used most economically in problem areas where slopes are very steep and unstable or where poor water management has resulted in confined flow.

The straw treatments are almost if not just as effective as the blankets, but are much more economical. The straw mulch can be applied to large areas and on moderate slopes and needs no tackifier. Also, a straw mulch, when tacked with a plastic net, such as Vexar, could be used in a situation where a blanket product must be used for comparable effectiveness, but for a much lower cost.

The hydromulches and chemical tackifiers have the lowest application cost per acre treatment and are the easiest to apply. However, the results of the tests showed that they were not as effective in controlling soil erosion as originally anticipated.

Hydromulches that were applied to test plots alone were easily dislodged by heavy rains and washed downslope. The chemical stabilizers which were tested in conjunction with only 500 pounds of wood fiber mulch per acre did not have the capability of preserving moisture at the soil surface. Larger quantities of mulch were required for soil moisture retention and to promote faster germination and more rapid vegetational growth.

Additional testing is needed for a variety of combinations of amounts of hydromulch and chemical stabilizers with cost of materials ranging from $200 to $300 on a per acre ($80 to $120 per hectare) basis. The formulation of an optimum blend of each component, which takes advantage of the merits of each treatment would be a valuable and economical treatment for erosion control.

COMPARISON WITH SEDIMENT YIELD DATA IN THE LITERATURE

Many other field tests, in addition to the test discussed in this report, have been conducted in recent years comparing the effectiveness of numerous soil erosion prevention and revegetation treatments. Although a significant amount of sediment yield data in response to various treatments exists in the literature, it has been very difficult to analyze these data in a comparative sense. In most cases, test conditions differ drastically, including climate, precipitation, soil types and slope characteristics, making test results difficult to evaluate.

One manner of comparison is to reduce all sediment yield data to a common base which would facilitate the evaluation of treatment effectiveness. The common base which was used is the VM factor discussed previously. VM values of 1.0 indicate that the treatment had no effect on stabilizing the soil or inhibiting erosion. The lower the VM value (expressed as a decimal), the more effective the soil stabilizing treatment.

The results of each field test found in the literature included at least one control plot of similar character but which had no treatment. From this relationship, it was possible to calculate VM factors for all the test data by taking the ratio of sediment eroded from the treated plot to the sediment yield of the control. The values are shown in Table 7 and can be used to compare the results derived from this study with those reported in the literature.

In general, the blanket products show consistently low VM values (i.e., effective soil stabilizers) and have the lowest values among the treatment types tested. However, the high initial cost and the increased installation time make these products unsuitable for large-scale reclamation tasks. These blanket treatments are especially suited for trouble spots where an unusually severe erosion problem is expected from a limited area; for example, drainage ditches or areas characterized by large runoff volumes.

The results show that the straw mulch treatments had the lowest VM values. Treatment rates of 1.5 to 2 tons of straw per acre (181 to 733 kg/ha) seemed to be quite sufficient to control erosion, either with or without an additional tacking agent. The next best treatment process involved the use of hydromulches, and the effectiveness had a mean VM value of about 0.237. Straw, however, is much less expensive than the hydromulches, which allows the straw to be applied at higher rates and with a tacking agent for a comparable lower cost. Although the study found that straw mulch only really needs a tackifier to resist high winds and runoff on very steep slopes, it did not, as was observed with wood and paper fiber hydromulches, tend to wash downslope in a tumbling fashion in large rainstorms, creating ridges of mulch and leaving behind large unprotected areas.

The plots treated with hydromulch and tackifier combinations show consistently higher VM values. The amount of hydromulch applied in these combination tests was reduced to compensate for the additional cost and expected effects of the tackifier. The plots treated only with chemical stabilizers produced

TABLE 7. COMPARISON OF EFFECTIVENESS OF EROSION REVEGETATION TREATMENTS BY VM FACTOR FOR FIELD TEST DATA

Reference Number	Treatment	Rate (per acre)	Rate (per hectare)	VM Factor
	HYDROMULCHES			
1	wood fiber mulch	1,000 lbs	183.6 kg	0.050
1	wood fiber mulch	1,400 lbs	256.9 kg	0.010
2	Conwed wood fiber mulch	1,000 lbs	183.6 kg	0.169-.304
*	Conwed wood fiber mulch	1,200 lbs	220.3 kg	0.235
*	Silva wood fiber mulch	1,200 lbs	220.3 kg	0.266
*	Turfiber	1,200 lbs	220.3 kg	0.655
*	Pulch	1,200 lbs	220.3 kg	0.280
2	Hardwood bark	27 cu yd	20.6 cu m	0.169
				mean=0.237
	CHEMICAL STABILIZERS			
1	Aquatain	---	---	0.680
2	Aquatain	10 lbs	1.84 kg	0.168
1	Aerospray 70	---	---	0.940
1	Curasol AK	---	---	0.300-.480
1	Petroset SB	---	---	0.400-.660
1	Terra Tack	---	---	0.660
2	Terra Tack	20 lbs	3.67 kg	0.659
3	Crust 500	480 gal	735 l	0.005
2	Genaqua 743	55 gal	84 l	0.235
2	M-145	72 gal	110 l	0.270
2	M-145	18 gal	27 l	0.675
				mean=0.470
	BLANKET PRODUCTS			
5	Hold gro	---	---	0.013
*	Hold gro	---	---	0.147
5	Excelsior	---	---	0.102
*	Excelsior	---	---	0.086
1	Excelsior	---	---	0.040-.100
*	Jute	---	---	0.110
4	Jute	---	---	0.037-.104
5	Jute	---	---	0.215
				mean=0.092

(Continued)

TABLE 7. COMPARISON OF EFFECTIVENESS OF EROSION REVEGETATION TREATMENTS BY VM FACTOR FOR FIELD TEST DATA

Reference Number	Treatment	Rate (per acre)	Rate (per hectare)	VM Factor
	STRAW MULCHES			
6	Straw, asphalt	2 tons, 450 gal	734 kg, 689 l	0.112
	Same treatment on four soil types			0.540 0.195 0.420
6	Straw, mixed	2 tons	734 kg	0.075
	Same four soil types, respectively			0.078 0.083 0.270
5	Straw, Vexar net	2 tons	734 kg	0.023
*	Straw, Vexar net	1.5 tons	550 kg	0.110
2	Straw, Curasol	1.5 tons, 40 gal	550 kg, 61 l	0.034
*	Straw, Curasol AK	1.5 tons, 45 gal	550 kg, 69 l	0.099
*	Straw, Dow	1.5 tons, 45 gal	550 kg, 69 l	0.021
*	Straw, Terra Tack	1.5 tons, 45 lbs	550 kg, 69 l	0.108
4	Straw, Terra Tack	---	---	0.013-.030
				mean=0.138
	HYDROMULCH AND TACKIFIER COMBINATIONS (wfm=wood fiber mulch)			
2	Aerospray 70 wfm	40 gal, 800 lbs	61 l, 147 kg	0.287
2	Aerospray 70 wfm	80 gal, 800 lbs	122 l, 147 kg	0.930
*	Aerospray 70 wfm	45 gal, 500 lbs	69 l, 91.7 kg	0.378
2	Curasol wfm	40 gal, 800 lbs	61 l, 147 kg	0.051
*	Curasol AK wfm	40 gal, 500 lbs	69 l, 91.7 kg	0.118
*	Petroset SB wfm	45 gal, 500 lbs	69 l, 91.7 kg	0.361
*	Genaqua 743 wfm	45 gal, 500 lbs	69 l, 91.7 kg	0.078
*	Perma Soil wfm	45 gal, 500 lbs	69 l, 91.7 kg	0.381
*	Terra Tack wfm	40 gal, 500 lbs	61 l, 91.7 kg	0.607
*	Crust 500 wfm	45 gal, 500 lbs	69 l, 91.7 kg	0.226
*	Dow wfm	45 gal, 500 lbs	69 l, 91.7 kg	0.185
				mean=0.327

REFERENCE NUMBERS LISTED IN TABLE 7

*	Data collected in this study
1	Utah Water Research Laboratory, 1976
2	Plass (1973)
3	Haines (1977)
4	Gaskin *et. al.* (1976)
5	Gulf States Paper (1977)
6	Barnet *et. al.* (1976)

the worst test results, but in most cases, the application rates were deliberately low in order to keep the treatment cost economically comparable with the other methods used. In another study, where Crust 500 was applied at a rate of 480 gal/acre (751 l/ha), the test results were excellent. Such a large application rate, however, is only feasible for small areas and for special dust control or fine grained soil stabilization purposes. Thus, to properly evaluate the performance of each treatment, it is necessary to consider the rate of application as well as the cost of materials, installation costs and sediment yield data.

REFERENCES

1. Barnet, A. P., E. G. Diseker and E. C. Richardson. Evaluation of Mulching Methods for Erosion Control on Newly Prepared and Seeded Highway Backslopes. Agriculture Journal, Vol. 59, 1967. pp. 83-88.

2. Ellerbe, C. South Carolina Soils and Their Interpretations for Selected Uses. South Carolina Land Resources Conservation Commission, Columbia, SC, 1974. 289 pp.

3. E.P.A. Erosion and Sediment Control: Surface Mining in the Eastern U.S. Vol. I Planning-Technology Transfer Seminar Publication, 1976a. pp. 38-41.

4. ________. Erosion and Sediment Control: Surface Mining in the Eastern U.S. Vol. II, Design-Technology Transfer Seminar Publication, 1976B. pp. 81-87.

5. Gaskin, D. A., W. Hannel and L. E. Stanley. Results of the 1974-1975 C.R.R.E.L. Terrain Stabilization Research/Demonstration Study. Technical Note, Dept. of Army Corps of Engineers, 1976. 44 pp.

6. Gulf States Paper. Report of the Sediment Yield Tests with Hold gro Erosion Control Fabric and Competitive Products. Special Report, Technical Services Division, Tuscaloosa, Alabama, 1977. 17 pp.

7. Guy, H. P. Laboratory Theory and Methods for Sediment Analysis. U.S.G.S. Techniques for Water Resources Investigations, Book 5, Chap. C-1, Supt. of Documents, Washington, D.C., 1969.

8. Haines, L. H. Personal Communication, U.S.D.I., Bureau of Reclamation.

9. Plass, Bill. Chemical Stabilizers for Surface Mine Reclamation. National Research Council Special Report, Highway Research Board, Washington, D.C., 1973. pp. 118-132.

10. S.C.S. National Engineering Field Manual for Conservation Practices. Chap. 2, Estimating Runoff. Engineering Branch, Hydrology Branch, Washington Advisory, Eng. 67, Supt. of Documents, Washington, D.C., 1971a. pp. 2.1-2.71.

11. S.C.S. Engineering Handbook. U.S. Dept. of Agriculture, Sect. 4, Hydrology, Chap. 10, Estimating Direct Runoff from Storm Rainfall. Supplement A. Supt. of Documents, Washington, D.C., 1971b. pp. 10.1-10.21.

12. S.C.S. Status of Land Disturbed by Mining as of January 1, 1974 by States. U.S.D.A. Interagency Memo, 1974. 6 pp.

13. Utah Water Research Laboratory. Erosion Control During Highway Construction. Manual of Erosion Control Principles and Practices, Vol. II. Utah State University, Logan, Utah, 1976. 93 pp.

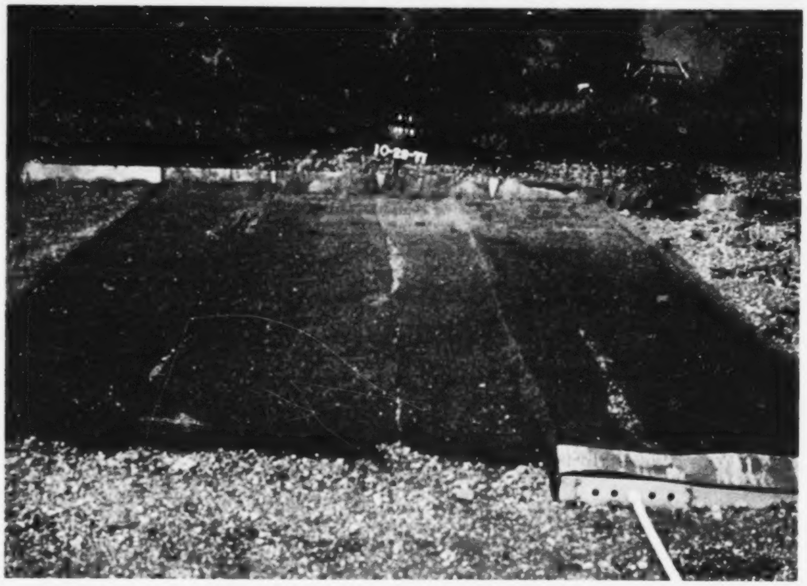
14. Young, R. A. and J. L. Wiersma. The Role of Rainfall Impact in Soil Detachment and Transport. Water Resources Research, Vol. 9, No. 6, 1973. pp. 1,629-1,636.

APPENDIX

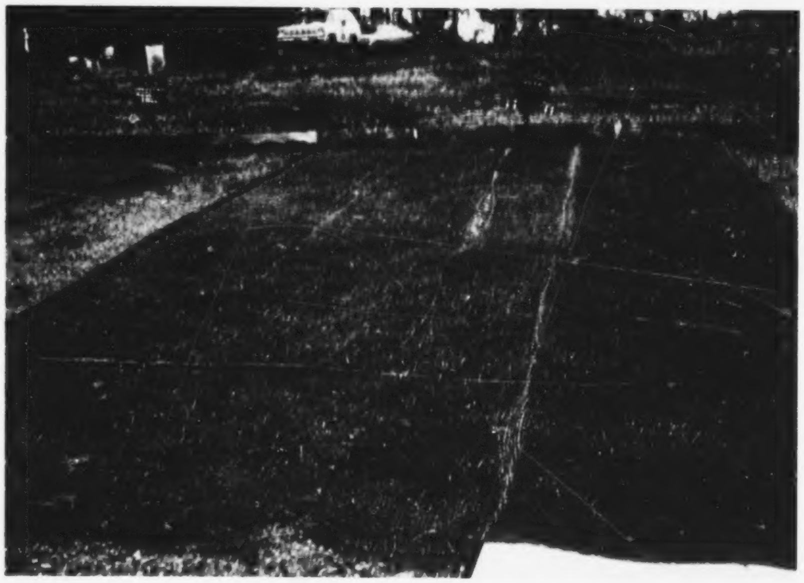
PHOTOGRAPHIC REPRESENTATION OF TREATMENT RESPONSE FROM 10/18/77 THROUGH 1/23/78

PLATE 1

PLOT A-1; JUTE NETTING

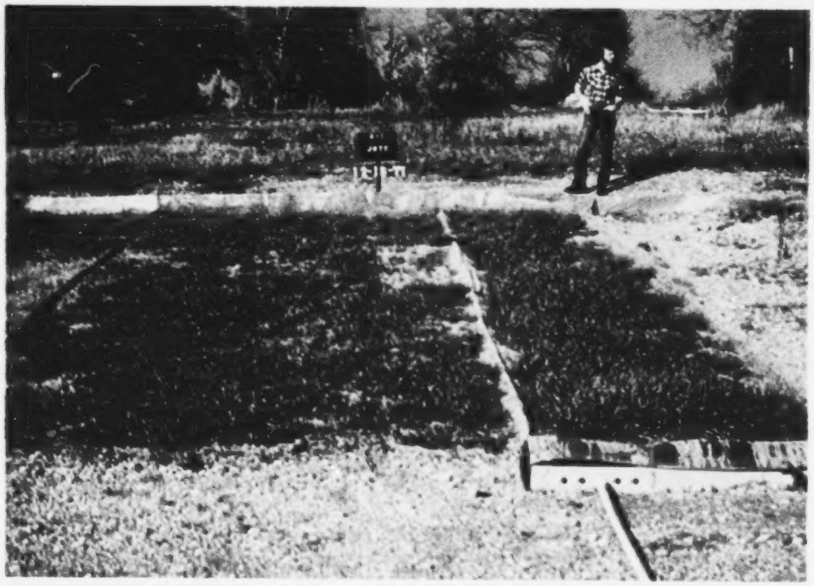


Plot A-1. (a). Jute netting was tested on plot A-1. Alternate wetting and drying caused netting shrinkage and produced gaps along the sidelaps (October 28, 1977).

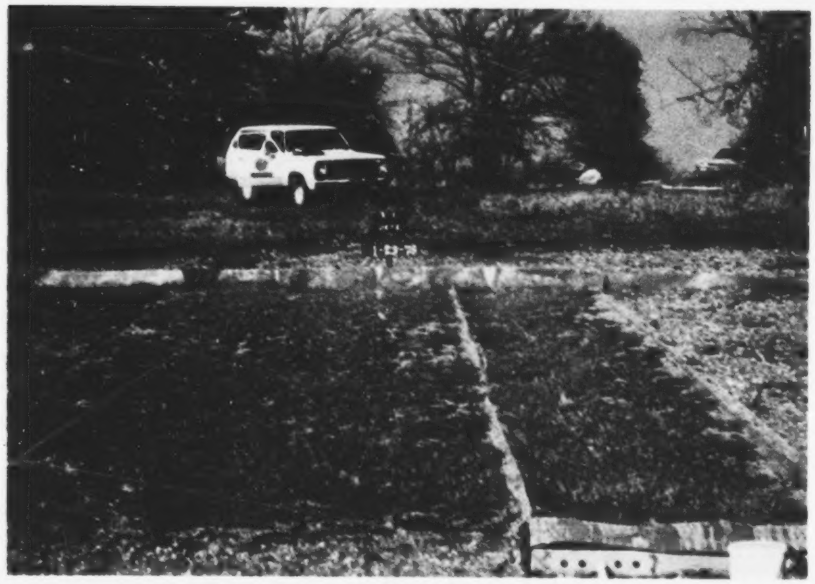


(b). Appearance of plot on November 28, 1977.

PLATE 1 (Continued)
PLOT A-1; JUTE NETTING

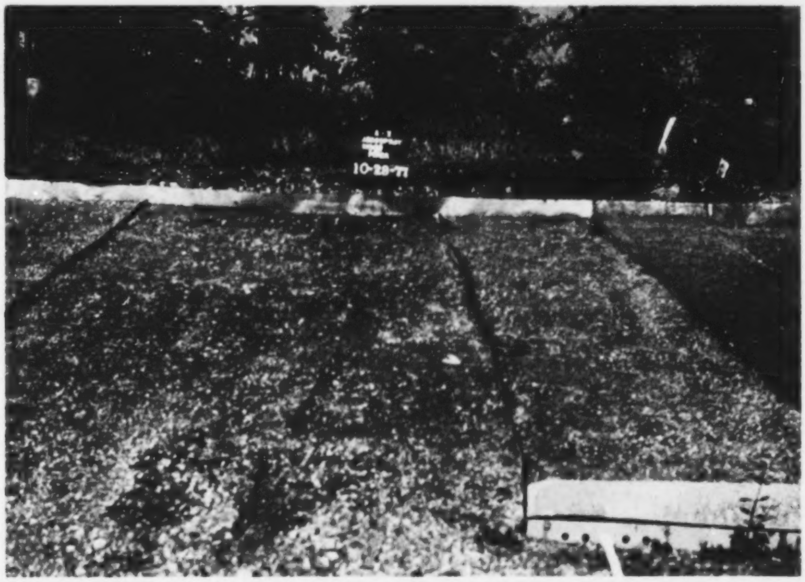


(c). Appearance of plot on December 15, 1977.

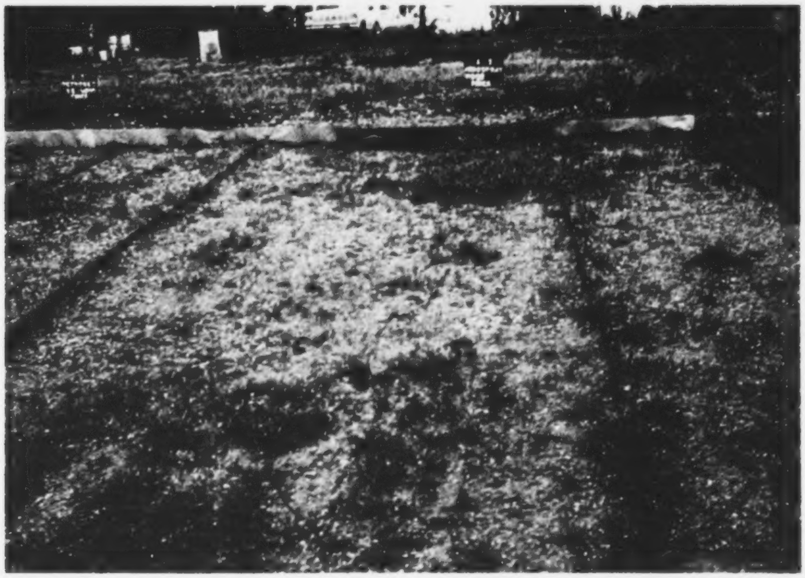


(d). Appearance of plot on January 23, 1977.

PLATE 2
PLOT A-2; AEROSPRAY (DCA-70) AND WOOD FIBER MULCH

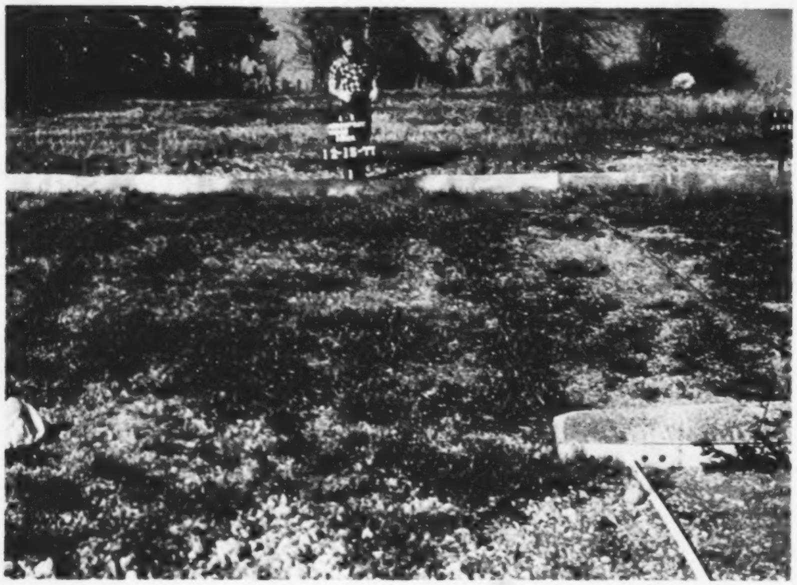


Plot A-2 (a). A breach in the drainage diversion plate caused advanced erosion to take place in the demonstration portion of the plot. However, the soil had formed a crust with the tackifier and severe erosion was prevented (October 28, 1977).

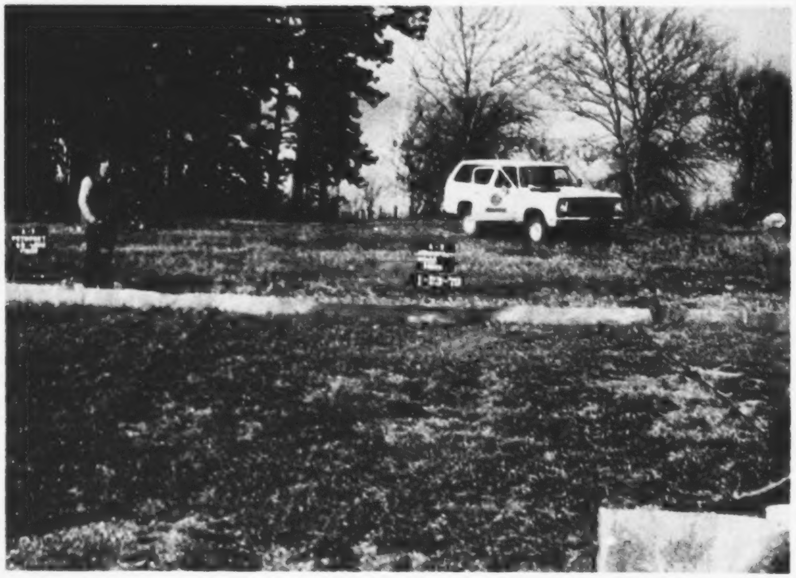


(b). Appearance on November 28, 1977.

PLATE 2 (Continued)
PLOT A-2; AEROSPRAY (DCA-70)AND WOOD FIBER MULCH

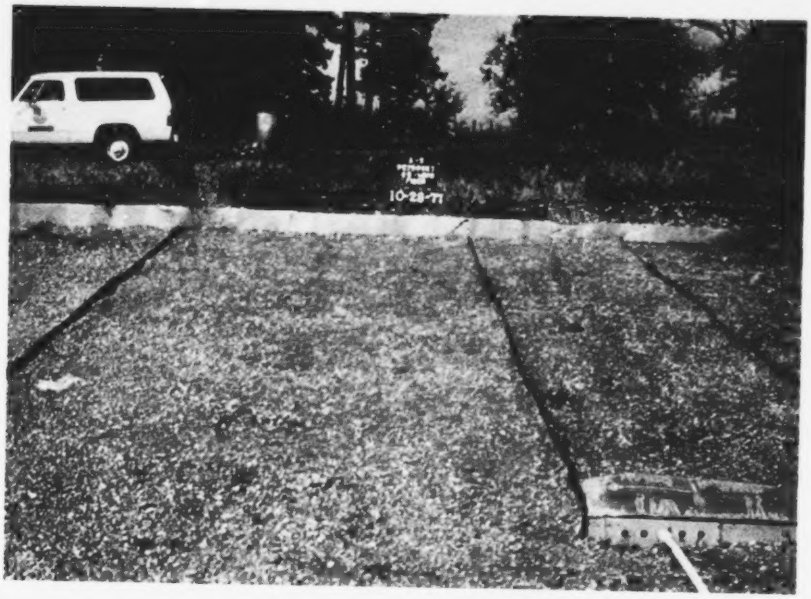


(c). Appearance on December 15, 1977.

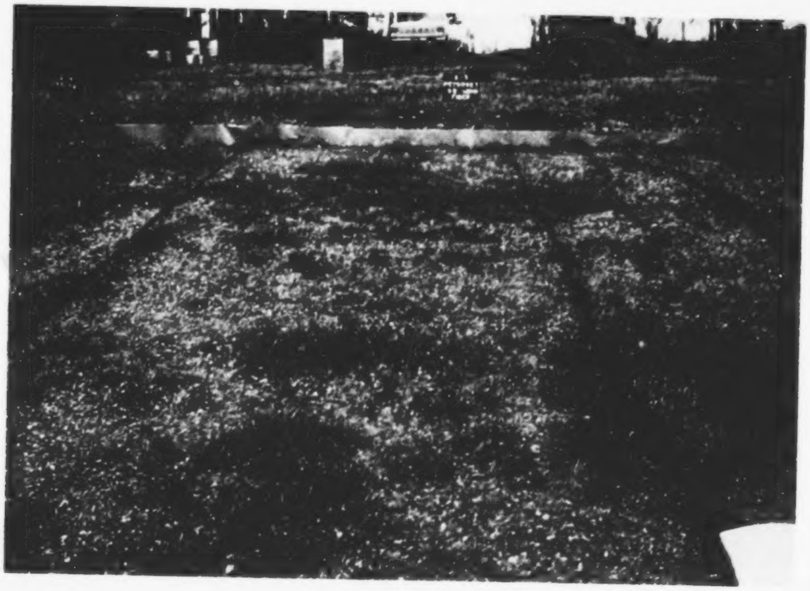


(d). Appearance on January 23, 1977.

PLATE 3
PLOT A-3; PETROSET SB WITH WOOD FIBER MULCH

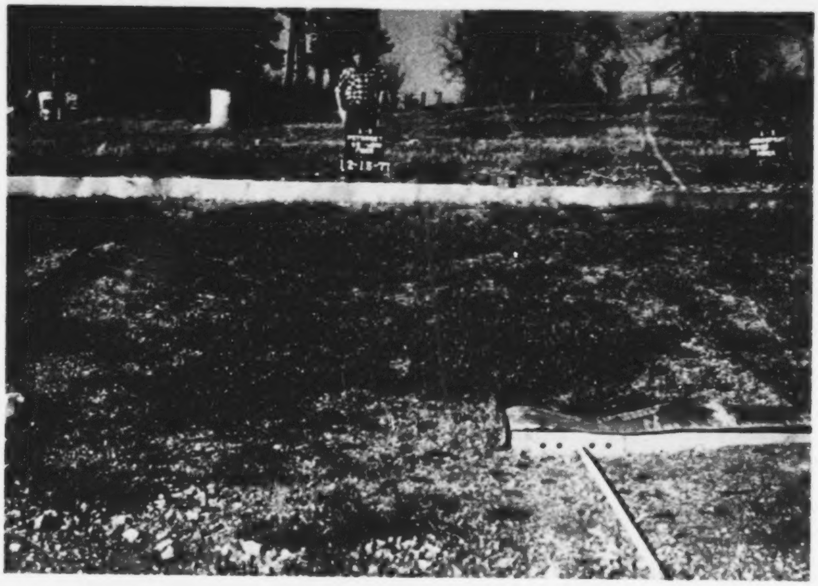


Plot A-3 (a). Plot was treated with Petroset SB tackifier over wood fiber mulch. Some soil crusting was noticed which inhibited severe erosion at the base of the plot (October 28, 1977).



(b). Appearance on November 28, 1977.

PLATE 3 (Continued)
PLOT A-3; PETROSET SB WITH WOOD FIBER MULCH

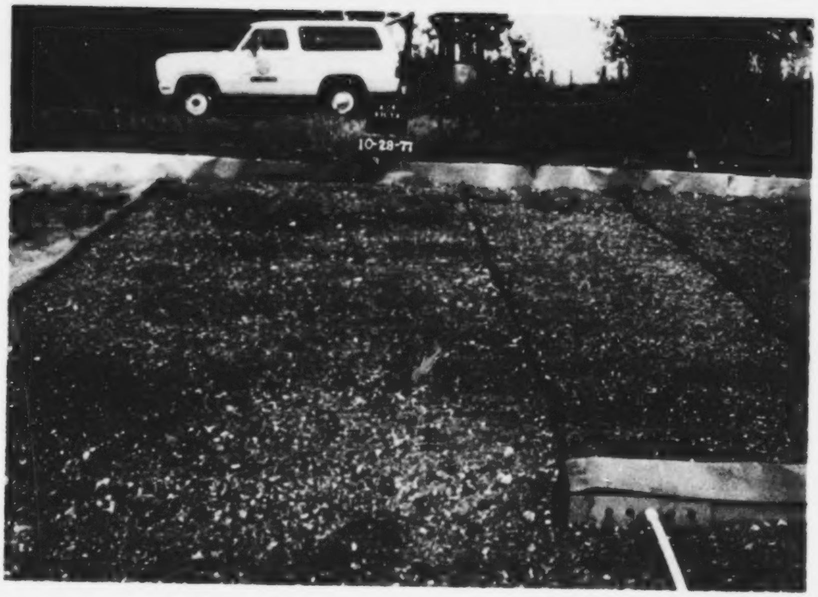


(c). Appearance on December 15, 1977.

PETROSET
1-23-78

(d). Appearance on January 23, 1977.

PLATE 4
PLOT A-4; SILVA FIBER



Plot A-4 (a).

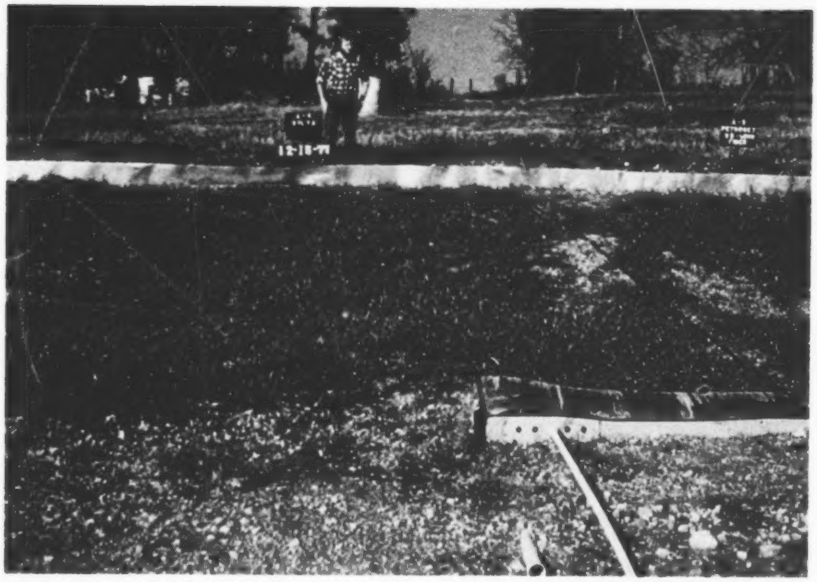
Plot A-3 (b).

(a). Appearance on October 28, 1977. Notice the concentration of seedlings in the upper left-hand portion of the plot.

(b). The mulch appeared to move downslope and gathered in ribs oriented transverse to the slope. These ribs formed as the material was washed and became caught in pebbles and small stones (October 28, 1977).

PLATE 4 (Continued)
PLOT A-4; SILVA FIBER

(c). Appearance on November 28, 1977.

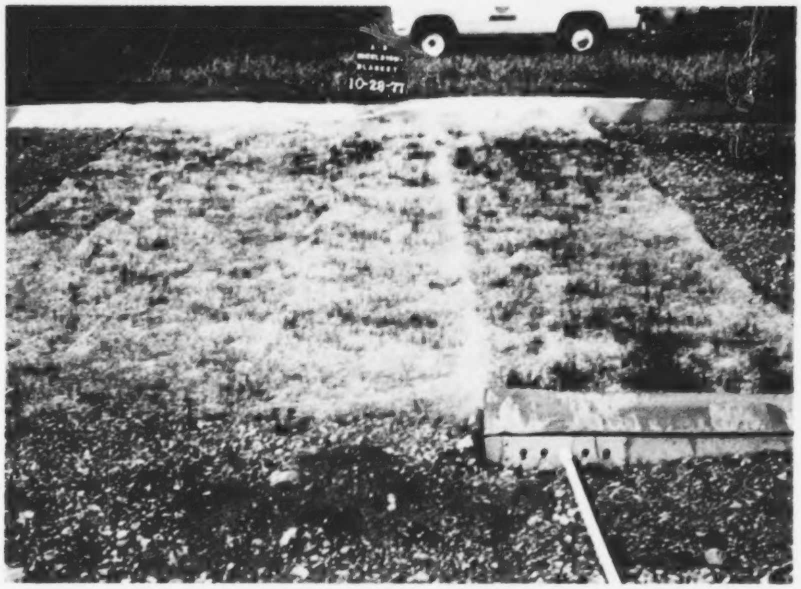


(d). Appearance on December 15, 1977.

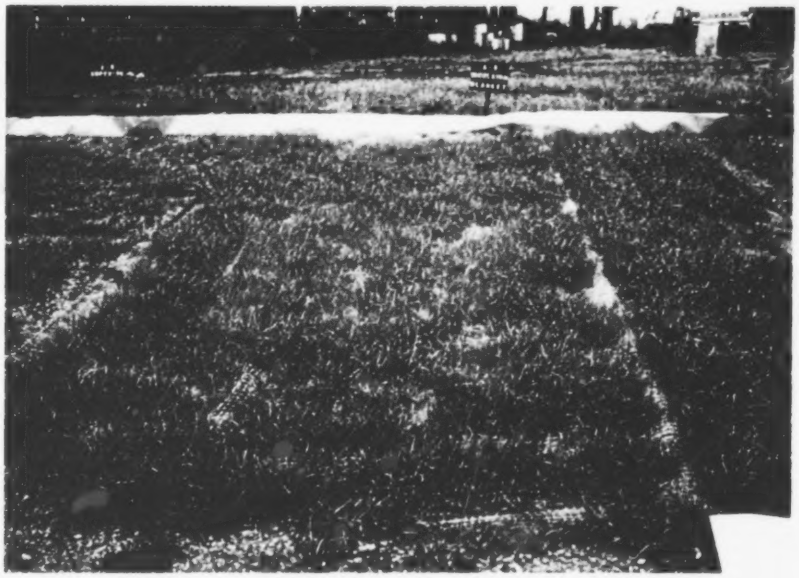
PLATE 4 (Continued)
PLOT A-4; SILVA FIBER

(e). Appearance on January 23, 1978.

PLATE 5
PLOT A-5; EXCELSIOR BLANKET

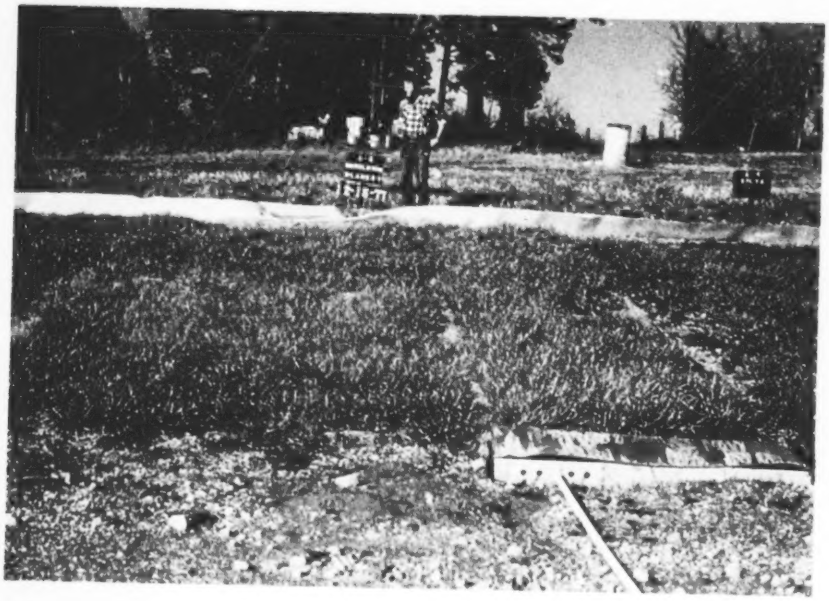


Plot A-5 (a). Excelsior blanket applied to plot A-5 provided a good initial grass cover. Seedlings on this plot appeared 50% taller than on any other test plot. Note the excelsior blanket is still 1½" (3.8 cm) thick and so hides the shorter seedlings from view (October 28, 1977).

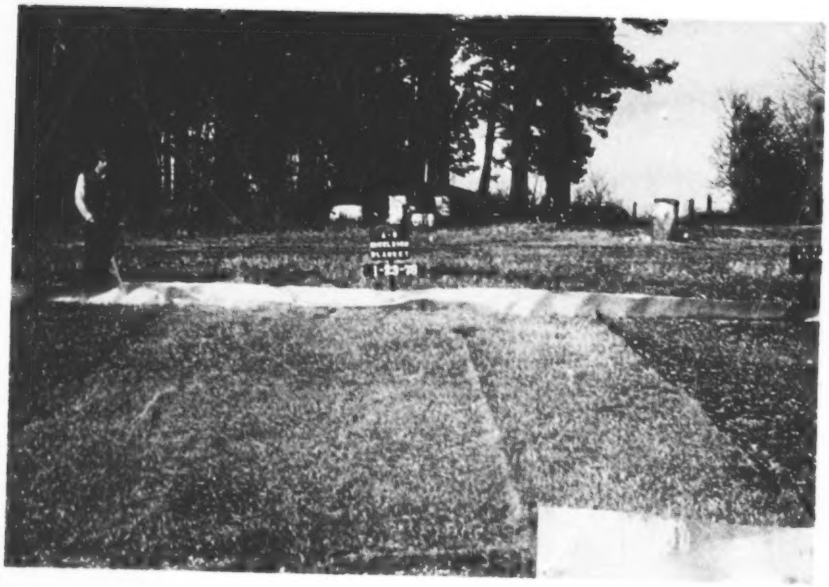


(b). Appearance on November 28, 1977.

PLATE 5 (Continued)
PLOT A-5; EXCELSIOR BLANKET



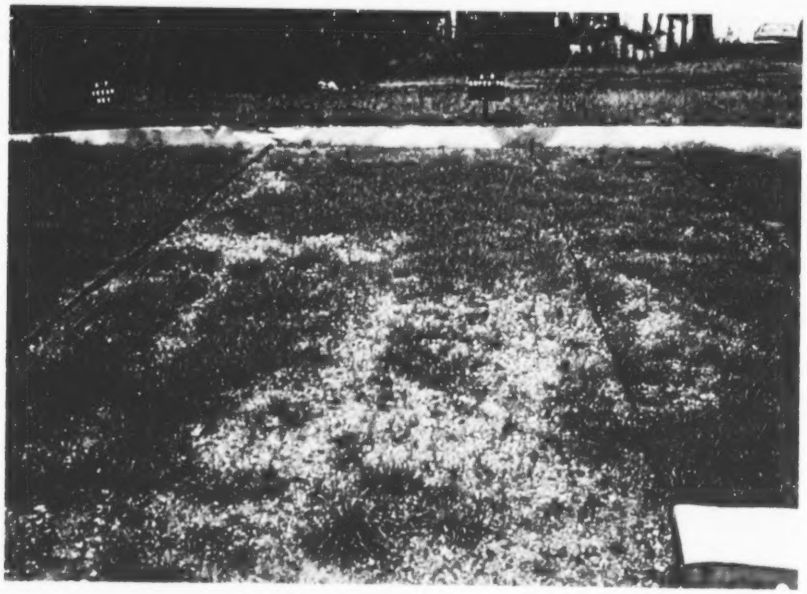
(c). Appearance on December 15, 1977.



(d). Appearance on January 23, 1978.

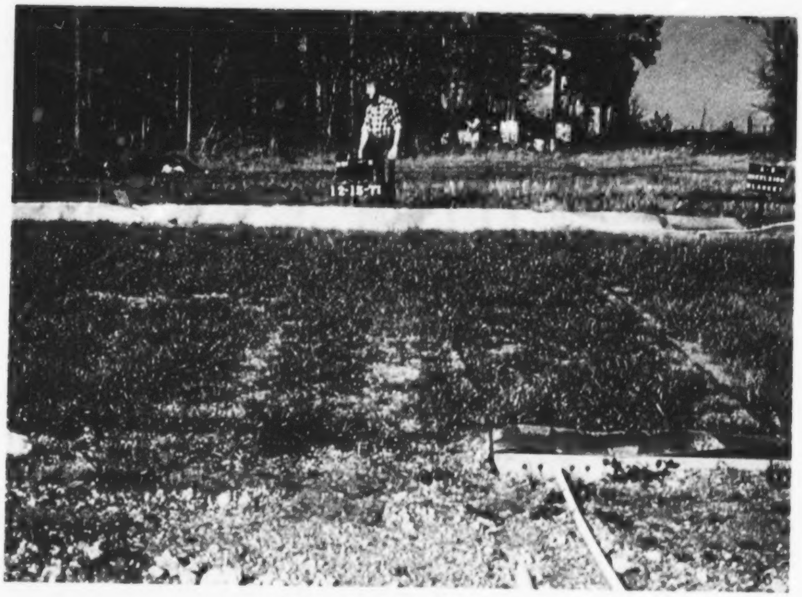
PLATE 6
PLOT A-6; SUPERIOR TURFIBER

Plot A-6 (a). This plot treated with Superior Turfiber shows development of a sparse vegetative cover (October 28, 1977).

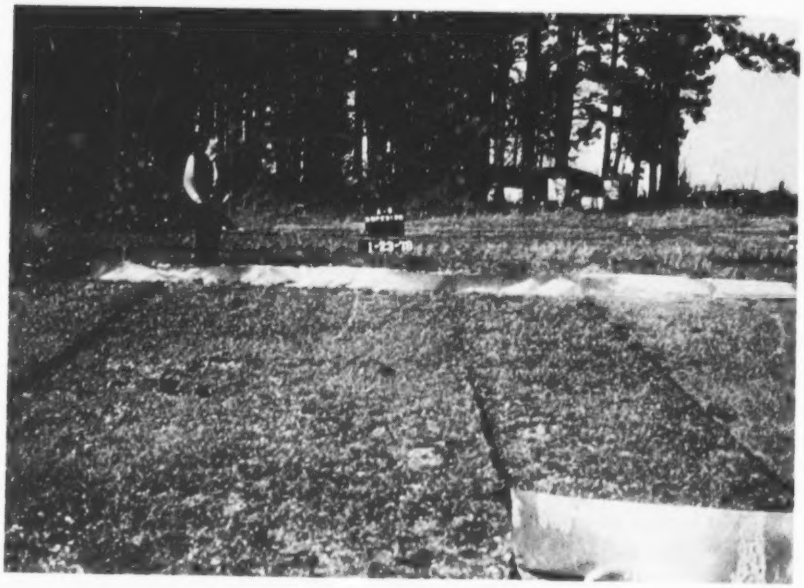


(b). Appearance on November 28, 1977.

PLATE 6 (Continued)
PLOT A-6; SUPERIOR TURFIBER

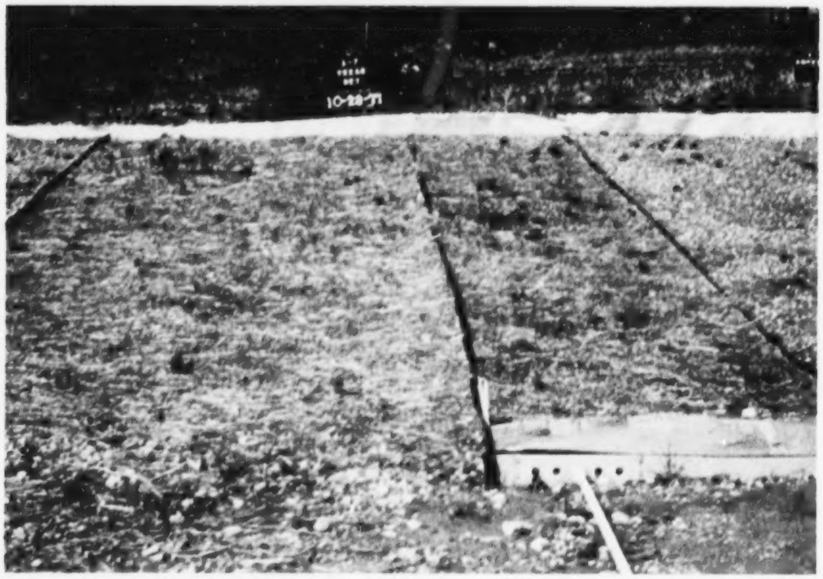


(c). Appearance on December 15, 1977.

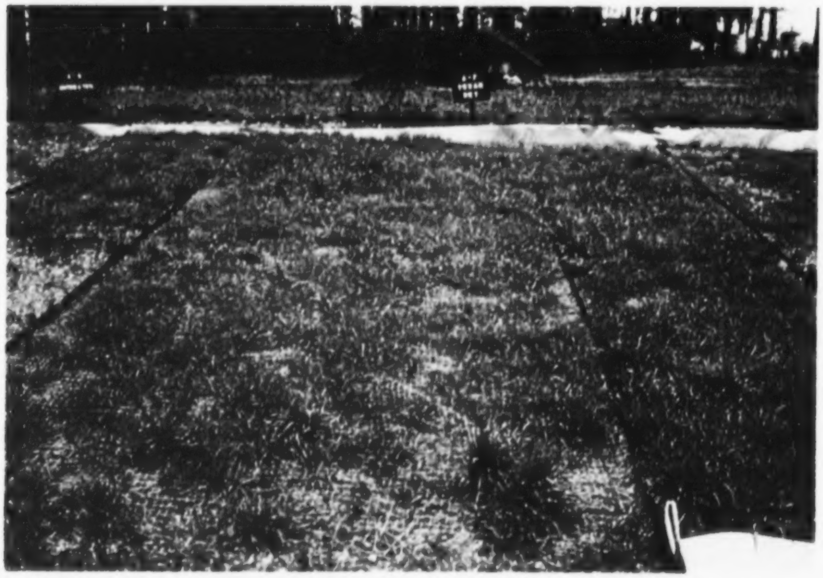


(d). Appearance on January 23, 1978.

PLATE 7
PLOT A-7; STRAW MULCH WITH VEXAR PLASTIC NET

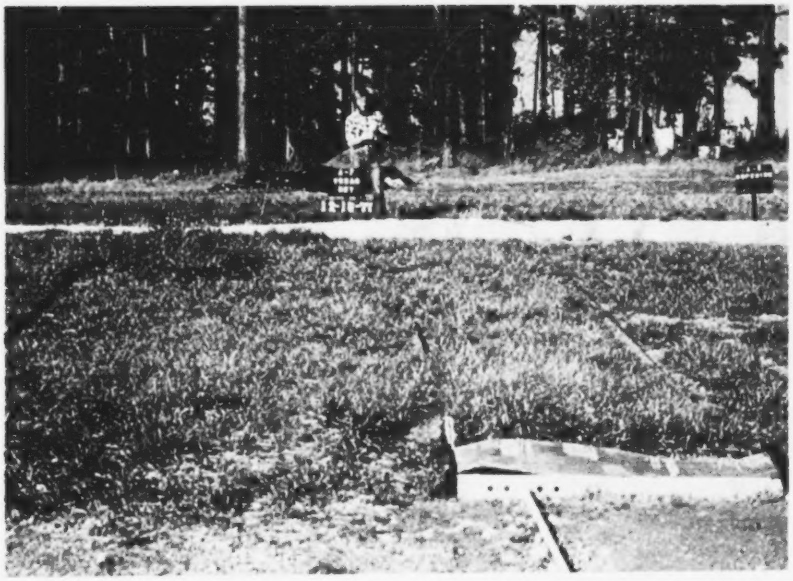


Plot A-7 (a). Straw mulch stabilized with Vexar plastic net (October 28, 1977).

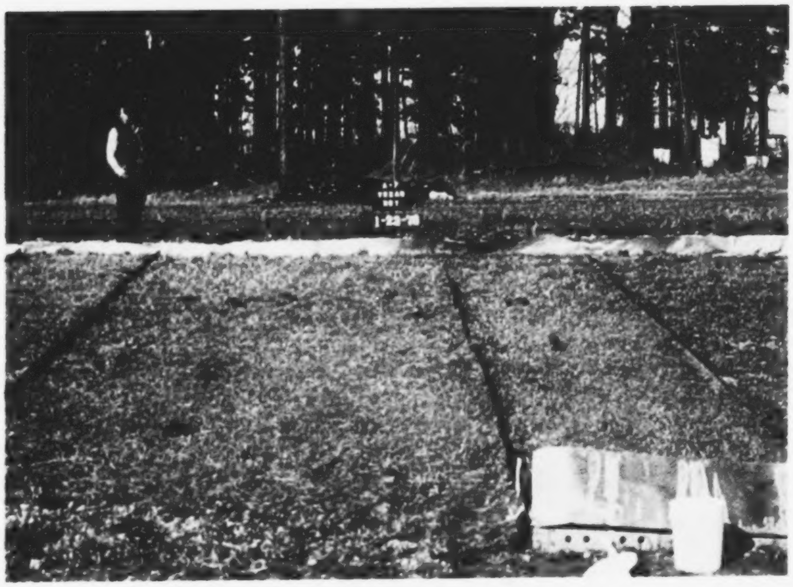


(b). Appearance on November 23, 1977.

PLATE 7 (Continued)
PLOT A-7; STRAW MULCH WITH VEXAR PLASTIC NET

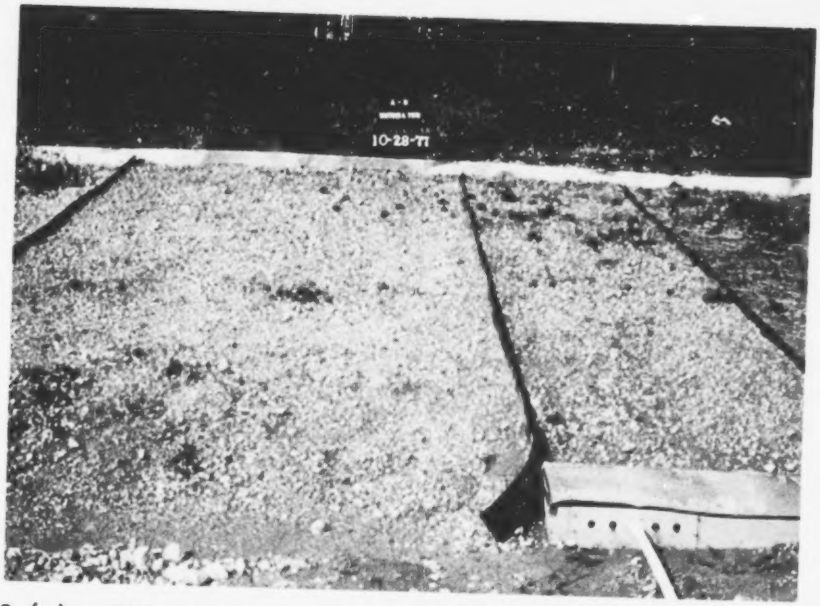


(c). Appearance on December 15, 1977.

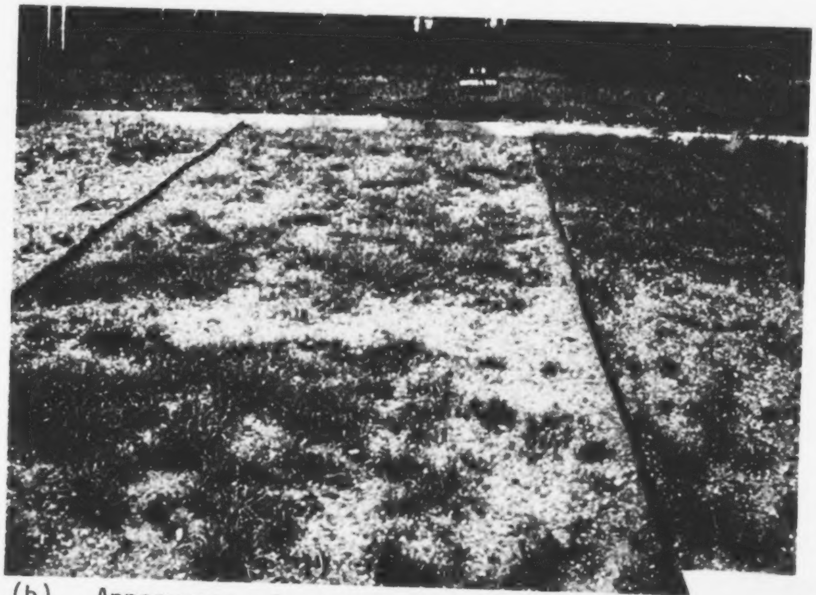


(d). Appearance on January 23, 1978.

PLATE 8
PLOT A-8; CONTROL FOR "A" HILLSLOPE

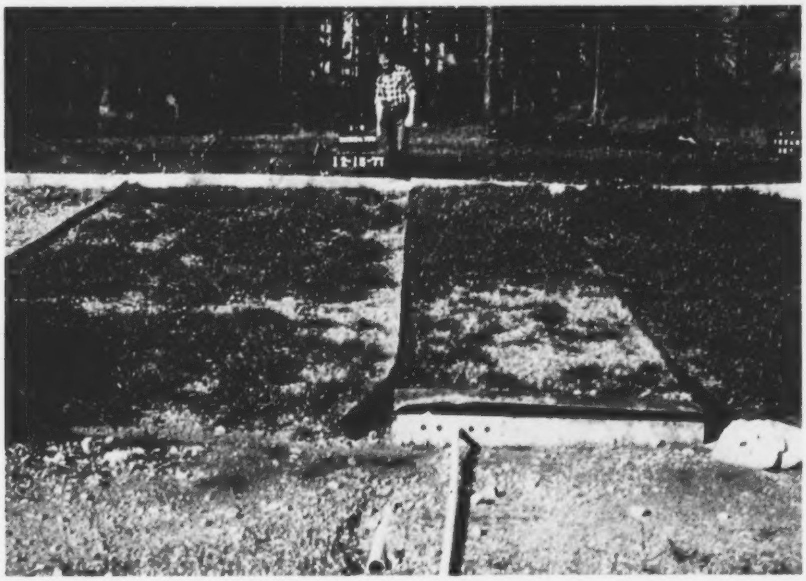


Plot A-8 (a). This plot was treated only with the standard fertilizer, lime and seed mixture. Severe gullying and pedestal erosion was noted (October 28, 1977).

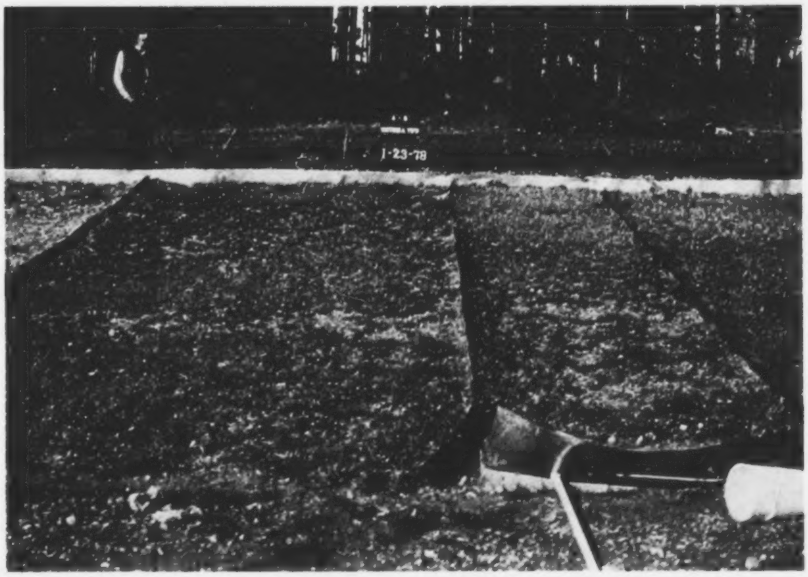


(b). Appearance of control plot on November 23, 1977.

PLATE 8 (Continued)
PLOT A-8; CONTROL FOR "A" HILLSLOPE

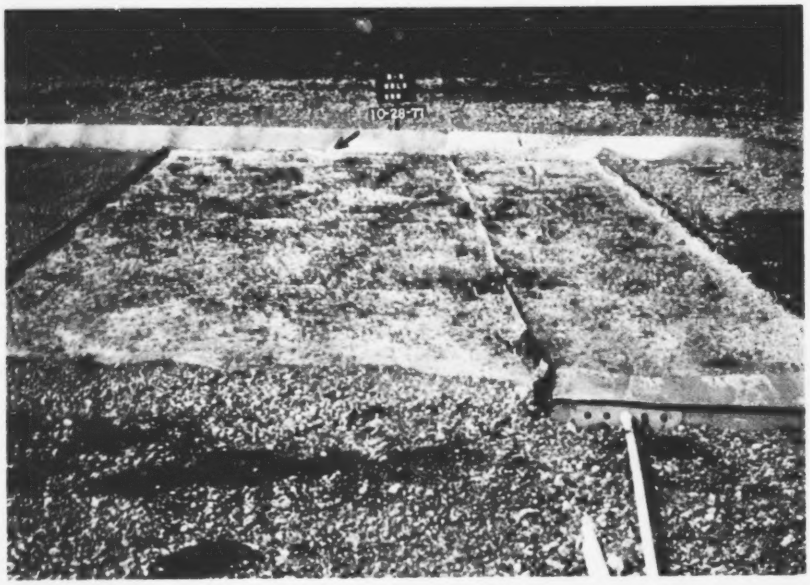


(c). Appearance on December 15, 1977.



(d). Appearance on January 23, 1978.

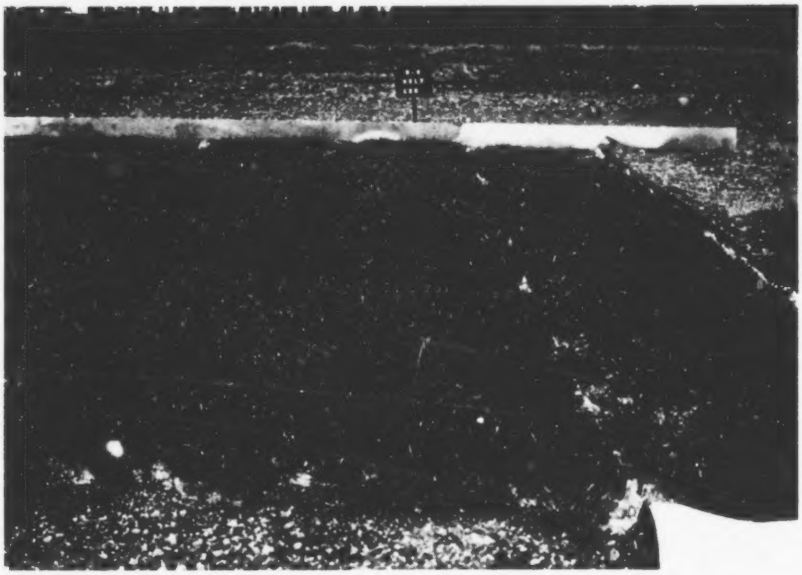
PLATE 9
PLOT B-9; HOLD GRO



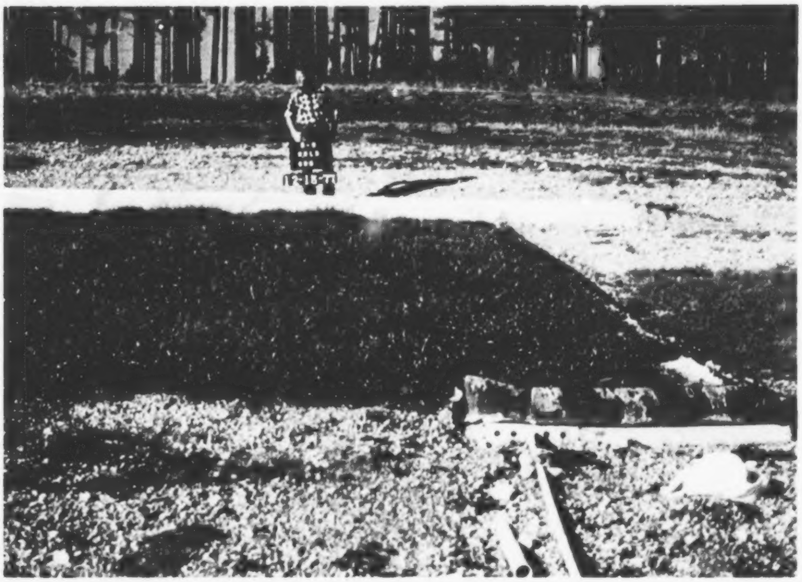
Plot B-9 (a). On October 28, 1977, this plot appeared to have the most dense seedling development. Some tenting (uplifting of the blanket cover by new vegetative growth) can be seen in the areas pointed to by arrows.

(b). Close-up view of tenting phenomenon (October 28, 1977).

PLATE 9 (Continued)
PLOT B-9; HOLD GRO

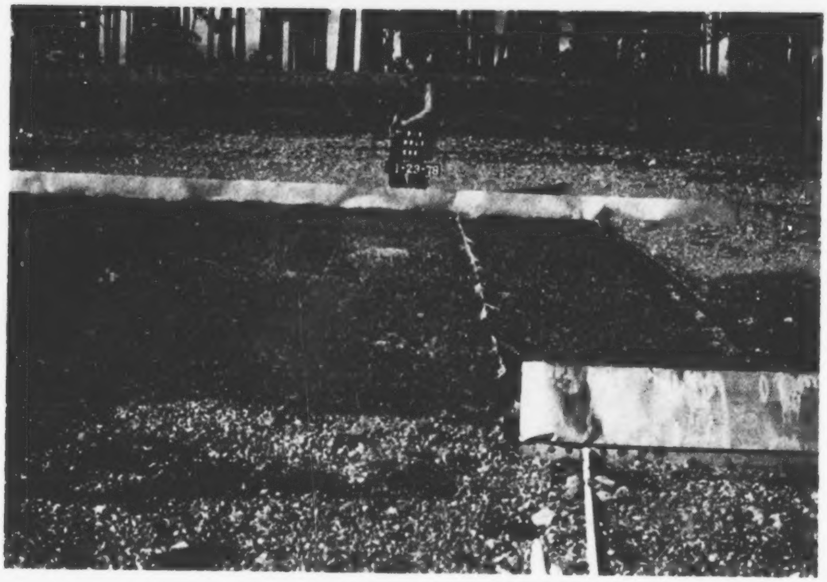


(c). Appearance on November 28, 1977.



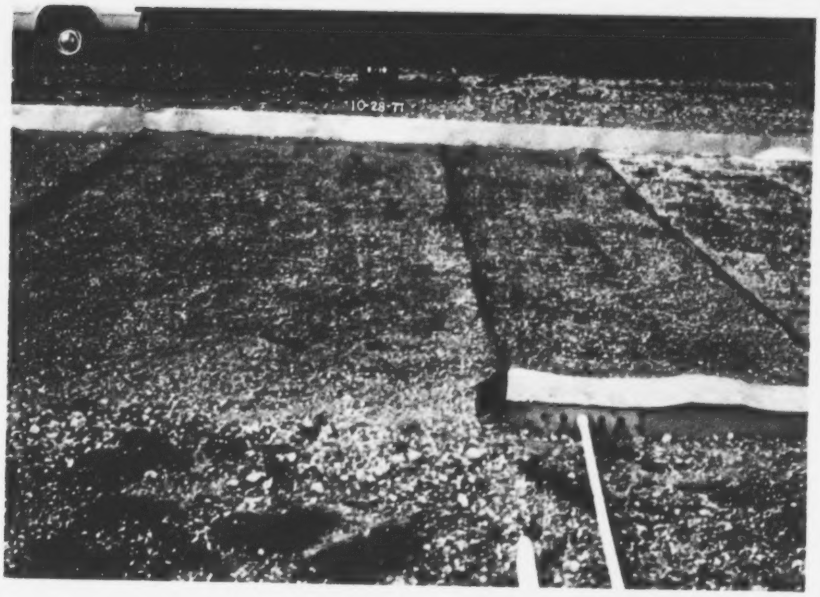
(d). Appearance on December 15, 1977.

PLATE 9 (Continued)
PLOT B-9; HOLD GRO

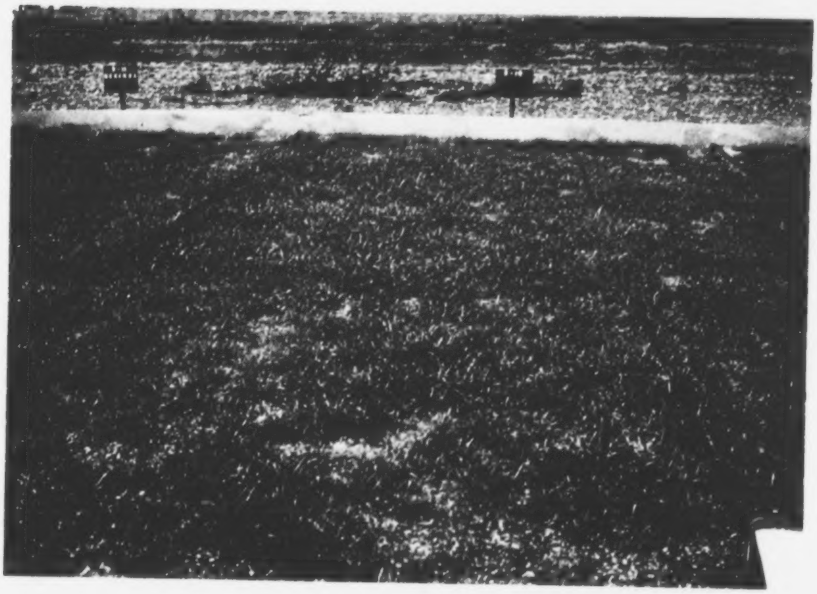


(e). Appearance on January 23, 1978.

PLATE 10
PLOT B-10; CURASOL AK AND WOOD FIBER

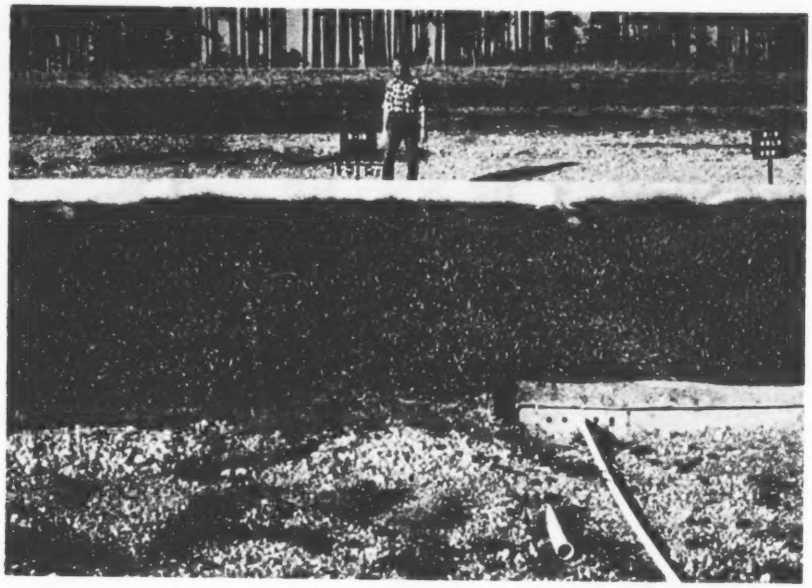


Plot B-10 (a). Plot treated with Curasol AK and wood fiber (October 28, 1977).

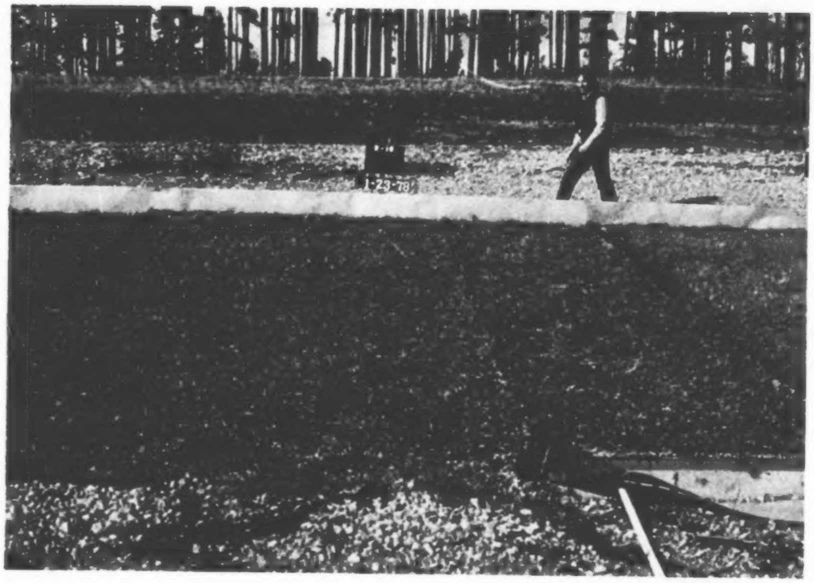


(b). Appearance on November 28, 1977.

PLATE 10 (Continued)
PLOT B-10; CURASOL AK AND WOOD FIBER



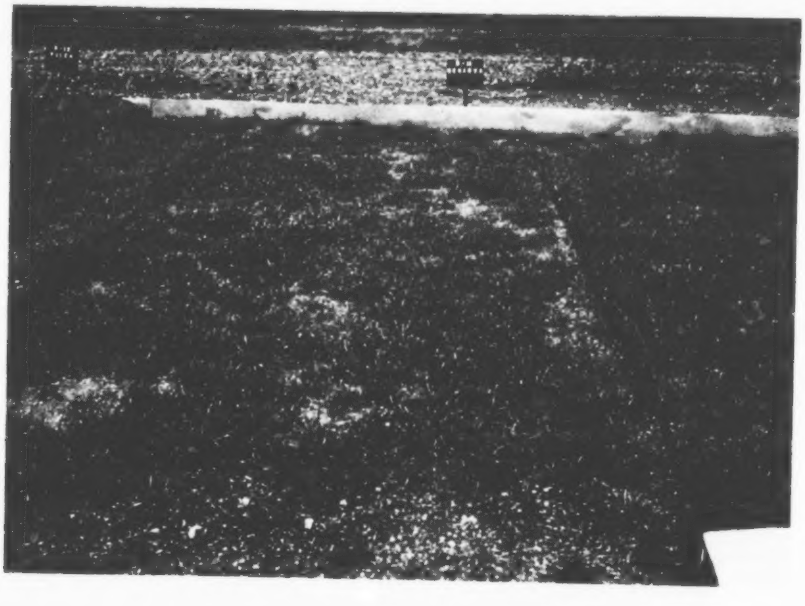
(c). Appearance on December 15, 1977.



(d). Appearance on January 23, 1978.

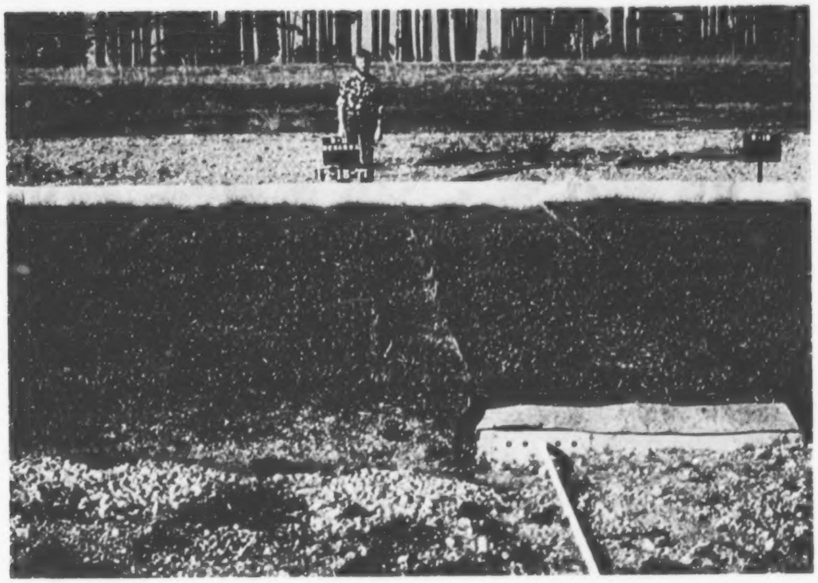
PLATE 11
PLOT B-11; GENAQUA 743 AND WOOD FIBER MULCH

Plot B-11 (a). Genaqua 743 was applied over wood fiber mulch (October 28, 1977).

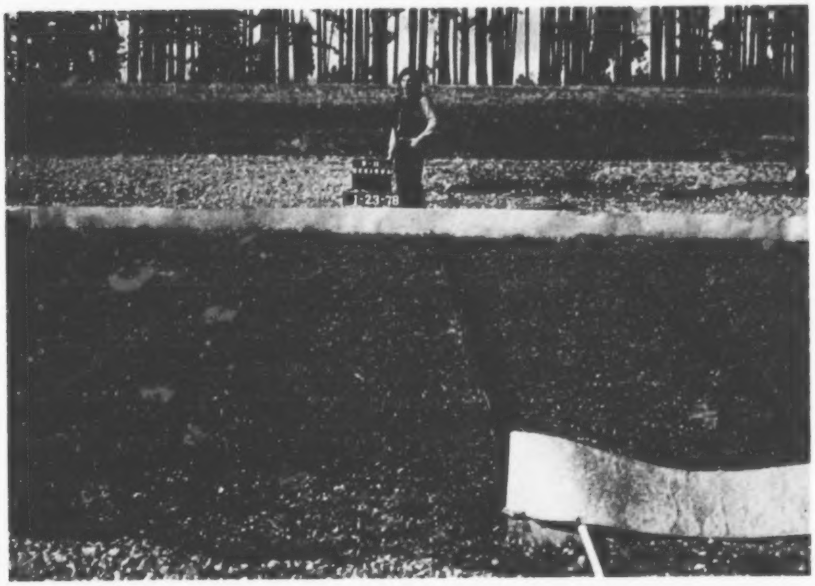


(b). Appearance on November 28, 1977.

PLATE 11 (Continued)
PLOT B-11; GENAQUA 743 WITH WOOD FIBER



(c). Appearance on December 15, 1977.



(d). Appearance on January 23, 1978.

PLATE 12
PLOT B-12; PULCH

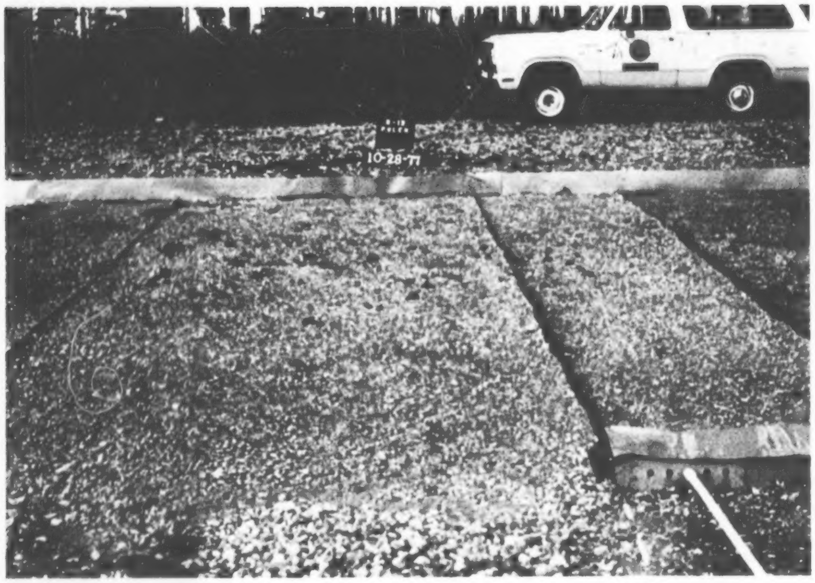


Figure B-12 (a).

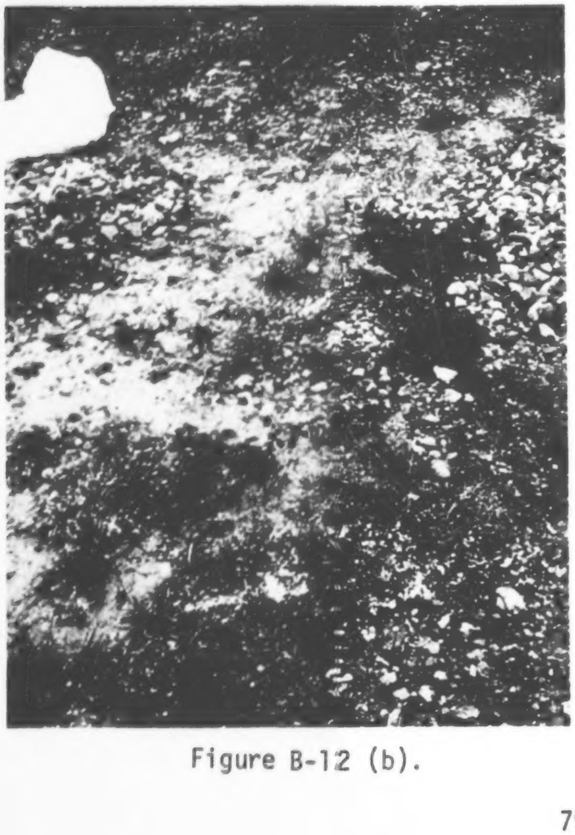
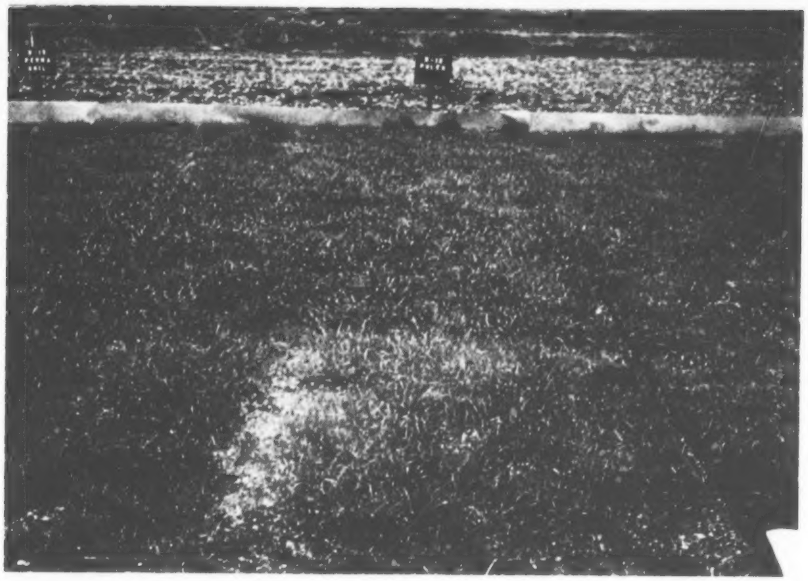


Figure B-12 (b).

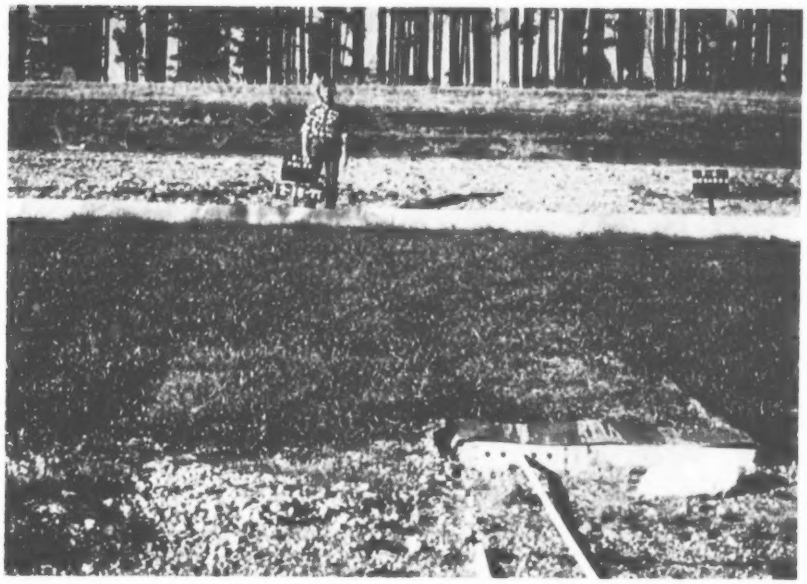
(a). This plot treated with Pulch hydromulch showed a sparse vegetative cover on October 28, 1977. Significant amounts of the mulch were found to be washed as far as 10 feet (3 m) out of the demonstration portion of the plot.

(b). Close-up of appearance on October 28, 1977.

PLATE 12 (Continued)
PLOT B-12; PULCH

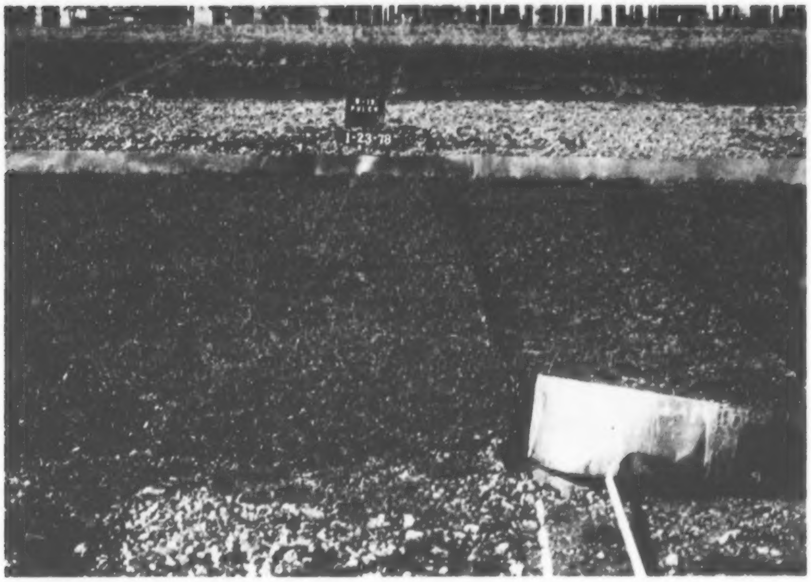


(c). Appearance on November 28, 1977.



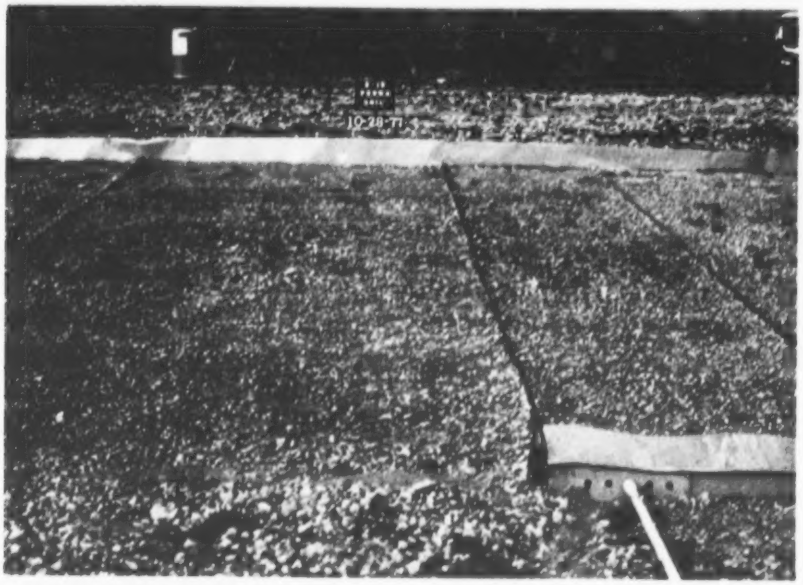
(d). Appearance on December 15, 1977.

PLATE 12 (Continued)
PLOT B-12; PULCH

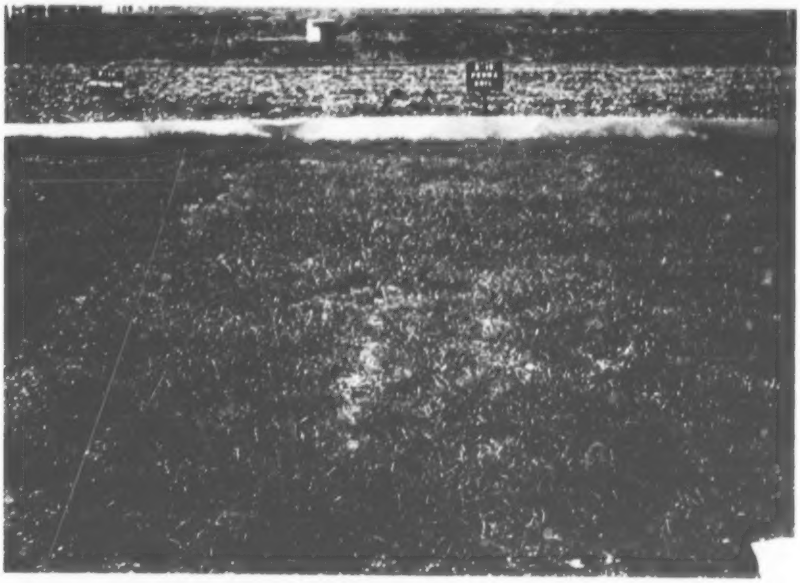


(e). Appearance on January 23, 1978.

PLATE 13
PLOT B-13; PERMA SOIL AND WOOD FIBER MULCH

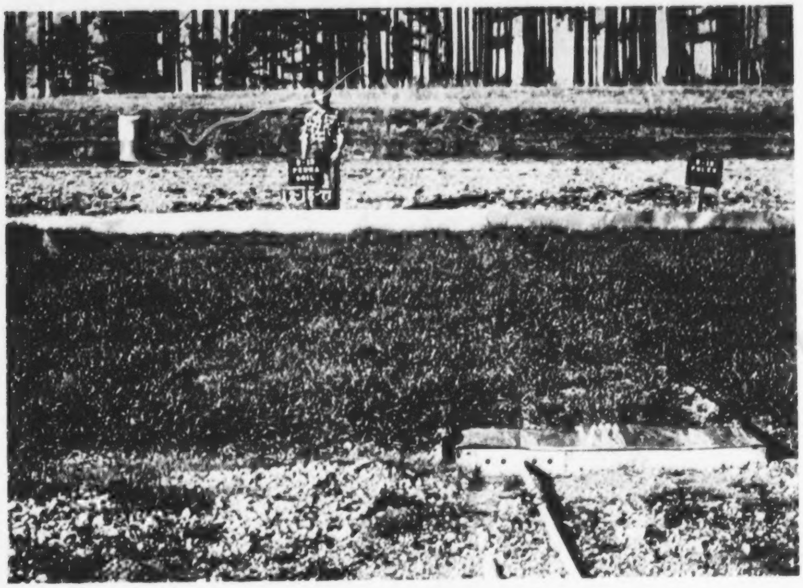


Plot B-13 (a). The downslope transport of the wood fiber mulch used in the tackifier test was most noticeable on this plot; October 28, 1977.

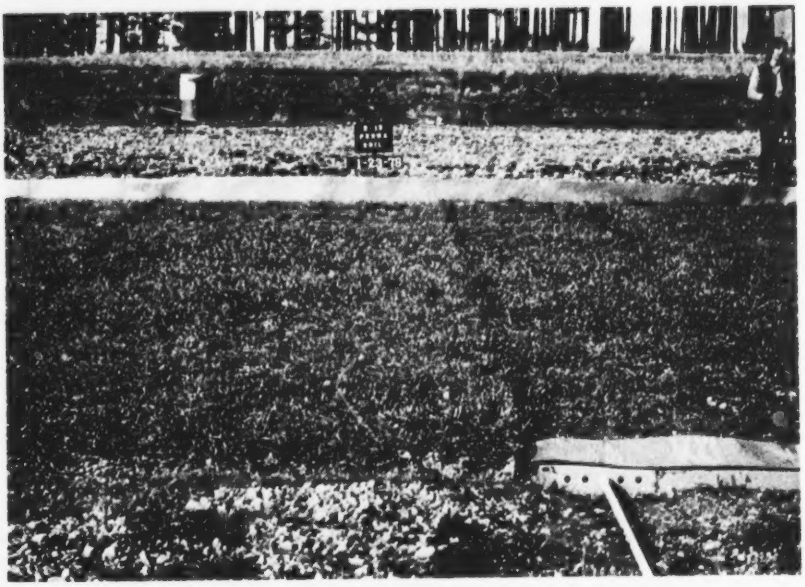


(b). Appearance on November 28, 1977.

PLATE 13 (Continued)
PLOT B-13; PERMA SOIL AND WOOD FIBER MULCH



(c). Appearance on December 15, 1977.



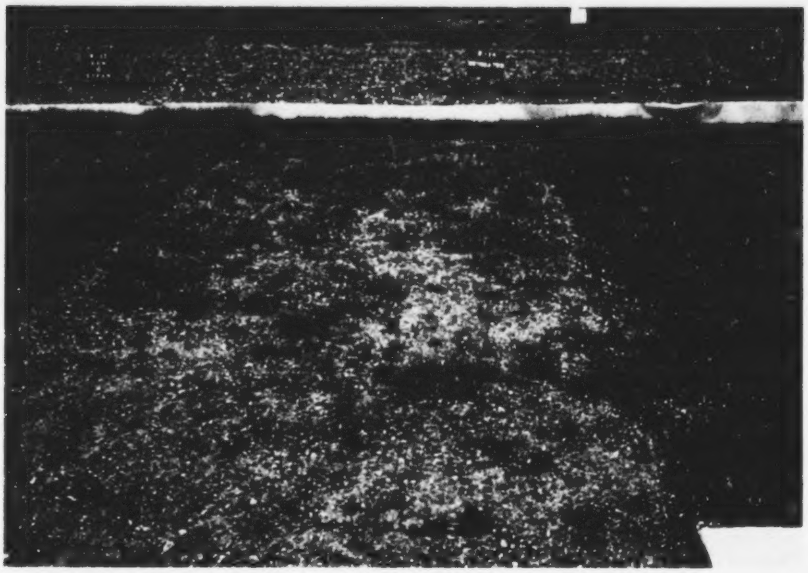
(d). Appearance on January 23, 1978.

PLATE 14
PLOT B-14; CONTROL FOR "B" HILLSLOPE

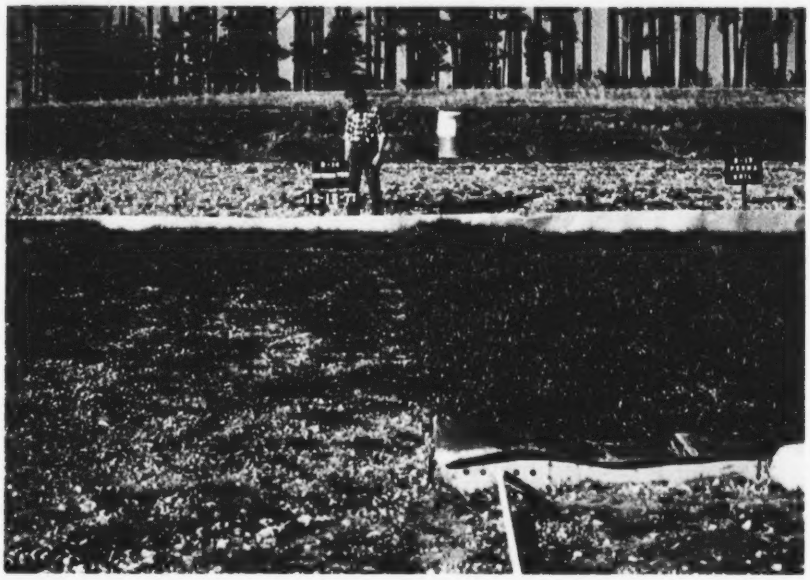
Plot B-14 (a). This plot was kept as a control for the "B" hillslope and only the standard fertilizer, lime and seed mixture was applied. Gulleying and pedestal erosion were found (October 28, 1977).

(b). Close-up of severe erosion exhibited on this plot (October 28, 1977).

PLATE 14 (Continued)
PLOT B-14; CONTROL FOR "B" HILLSLOPE



(c). Appearance on November 28, 1977.



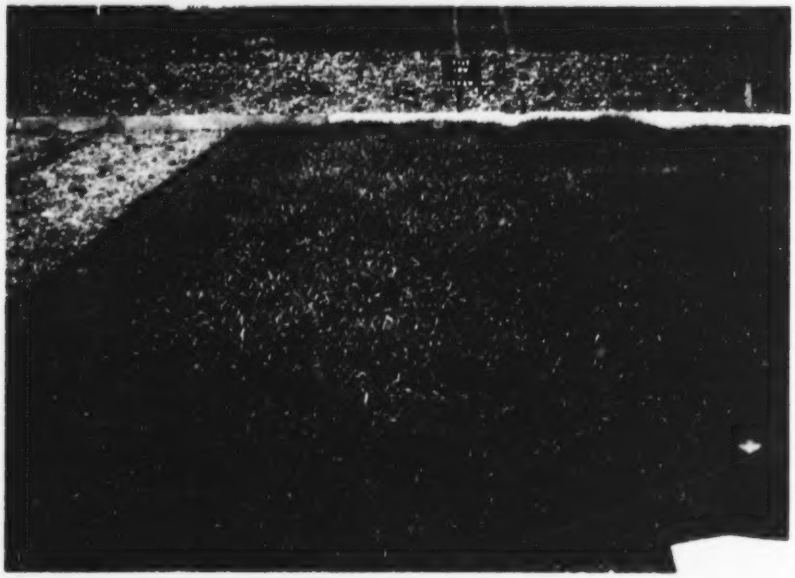
(d). Appearance on December 15, 1977.

PLATE 14 (Continued)
PLOT B-14; CONTROL FOR "B" HILLSLOPE

(e). Appearance on January 23, 1978.

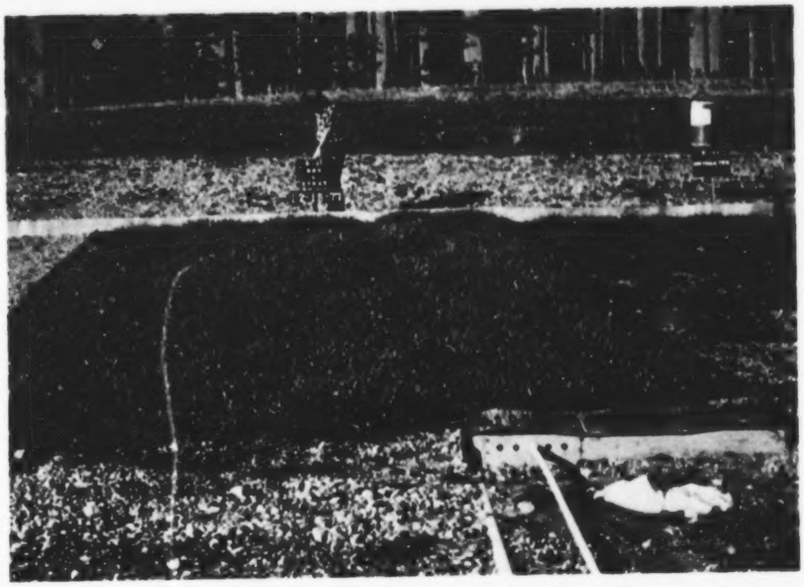
PLATE 15
PLOT B-15; DOW MULCH BINDER AND STRAW

Plot B-15 (a). This plot was treated with a straw mulch and Dow binder. On October 28, 1977, this plot had achieved one of the most advanced vegetative covers during this period.

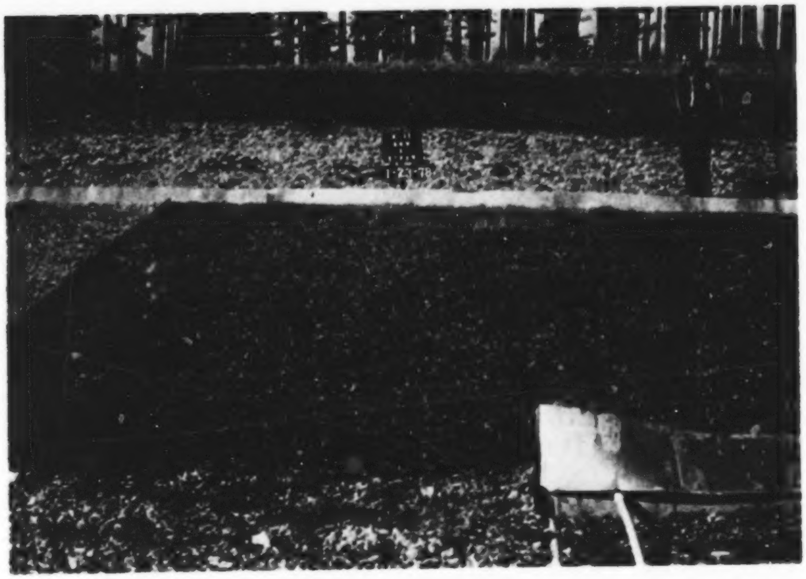


(b). Appearance on November 28, 1977.

PLATE 15 (Continued)
PLOT B-15; DOW MULCH BINDER AND STRAW

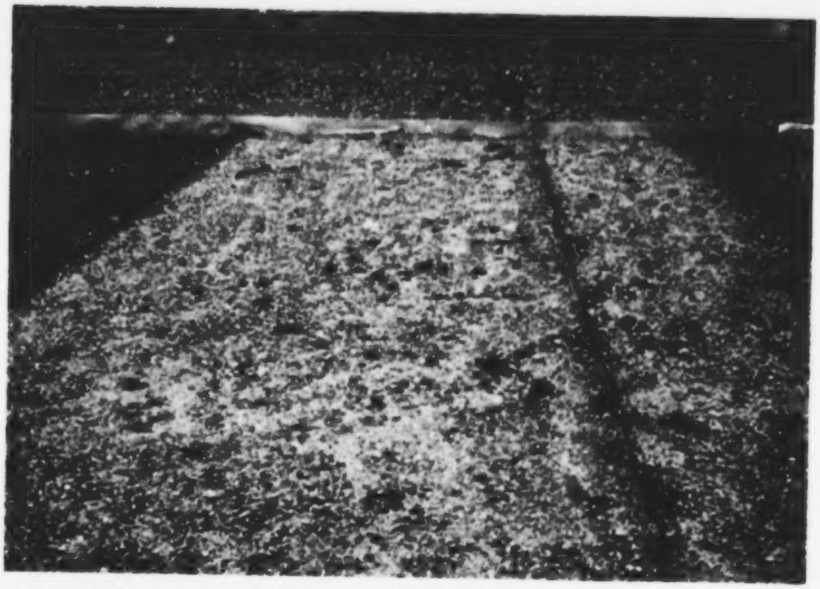


(c). Appearance on December 15, 1977.



(d). Appearance on January 23, 1978.

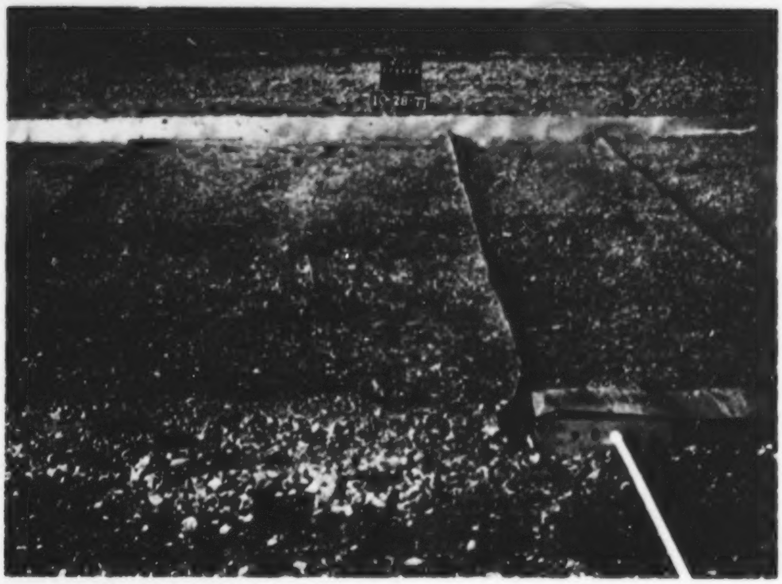
PLATE 16
PLOT B-16; UNTREATED



Plot B-16 (a). This plot was designated as a control for the "B" hillslope. The soil was disturbed and no treatment, amendments, or seed was applied.

(b). The almost total absence of vegetation at this point demonstrates the effectiveness of measures taken to eliminate regrowth of volunteer vegetation on the test plots (January 23, 1978).

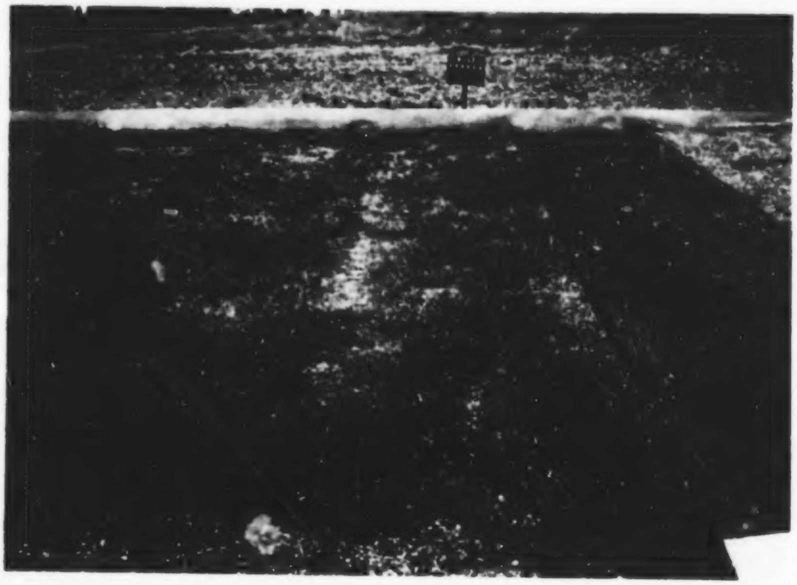
PLATE 17
PLOT B-17; CONWED AND WOOD FIBER MULCH



Plot B-17 (a). On October 28, 1977, this plot showed that the thin vegetative cover had developed more in the slightly lower lying areas in the center of the plot.

(b). The mulch showed a strong tendency to wash downslope and collect in ribs. Close-up of this characteristic on October 28, 1977.

PLATE 17 (Continued)
PLOT B-17; CONWED AND WOOD FIBER MULCH



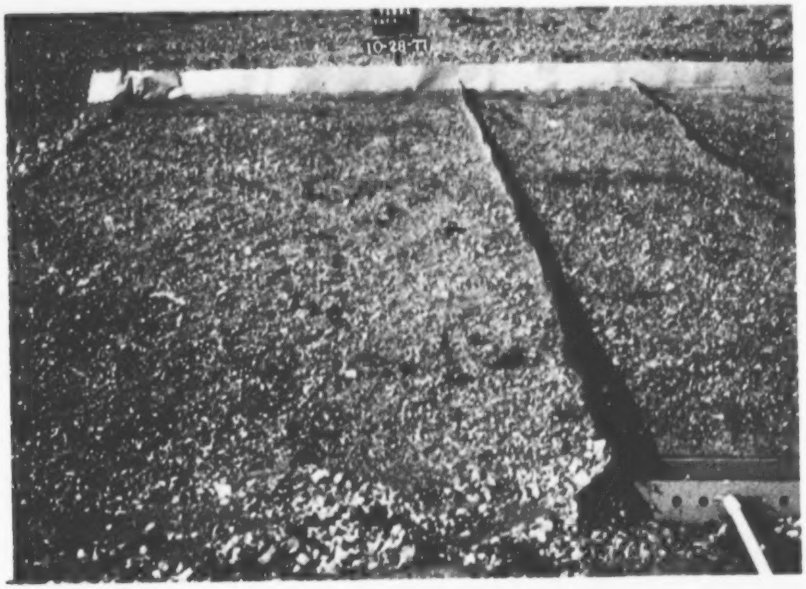
(c). Appearance on November 28, 1977.

(d). Appearance on December 15, 1977.

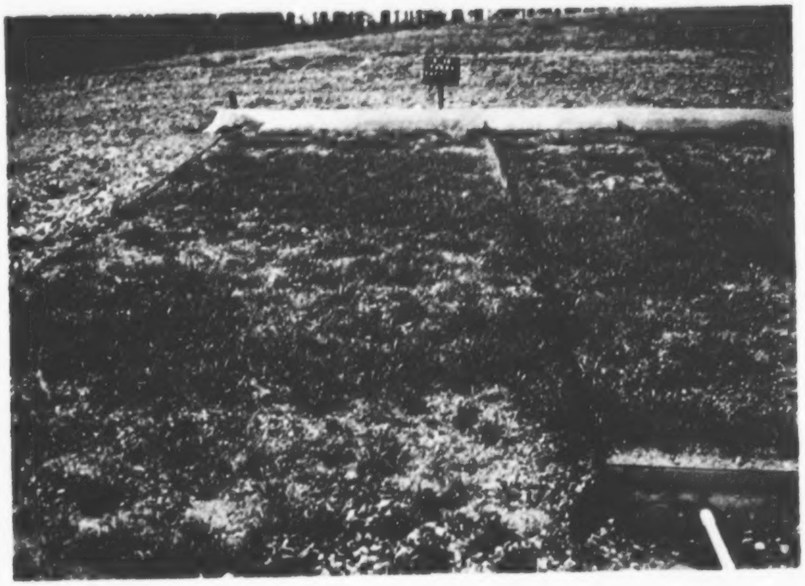
PLATE 17 (Continued)
PLOT B-17; CONWED AND WOOD FIBER MULCH

(e). Appearance on January 23, 1978.

PLATE 18
PLOT B-18; TERRA TACK III AND WOOD FIBER MULCH



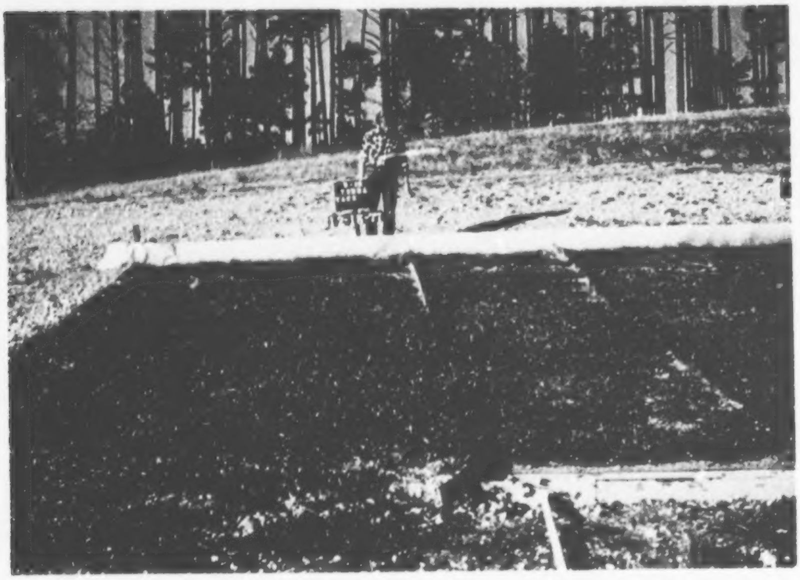
Plot B-18 (a). This plot was treated with Terra Tack III. Appearance on October 28, 1977.



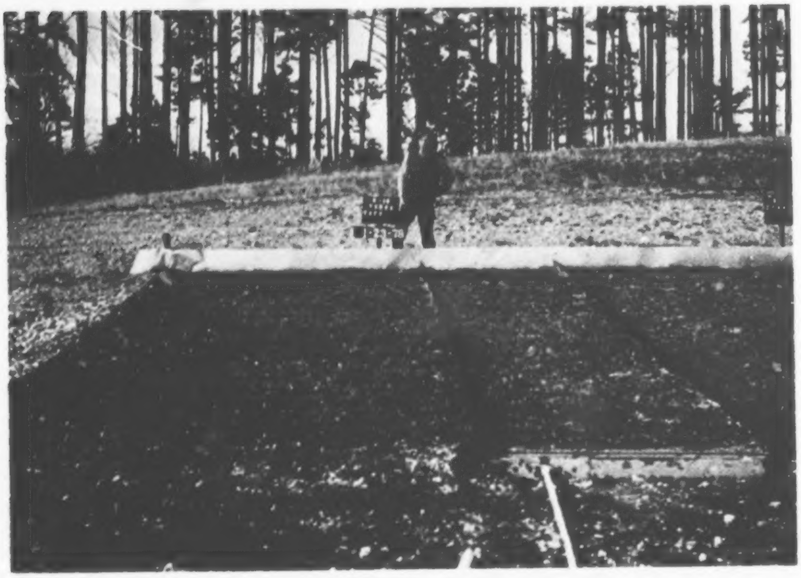
(b). Appearance on November 28, 1977.

PLATE 18 (Continued)

PLOT B-18; TERRA TACK III AND WOOD FIBER MULCH

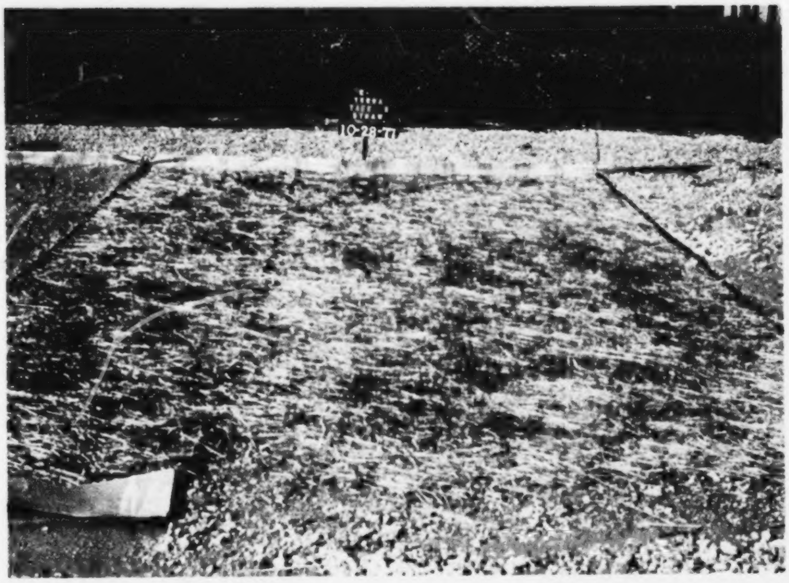


(c). Appearance on December 15, 1977.

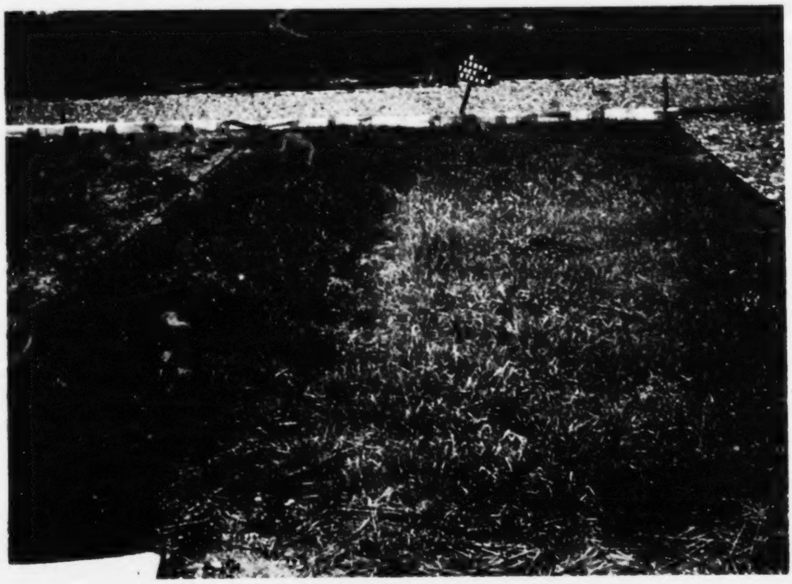


(d). Appearance on January 23, 1978.

PLATE 19
PLOT C-19; TERRA TACK II AND STRAW

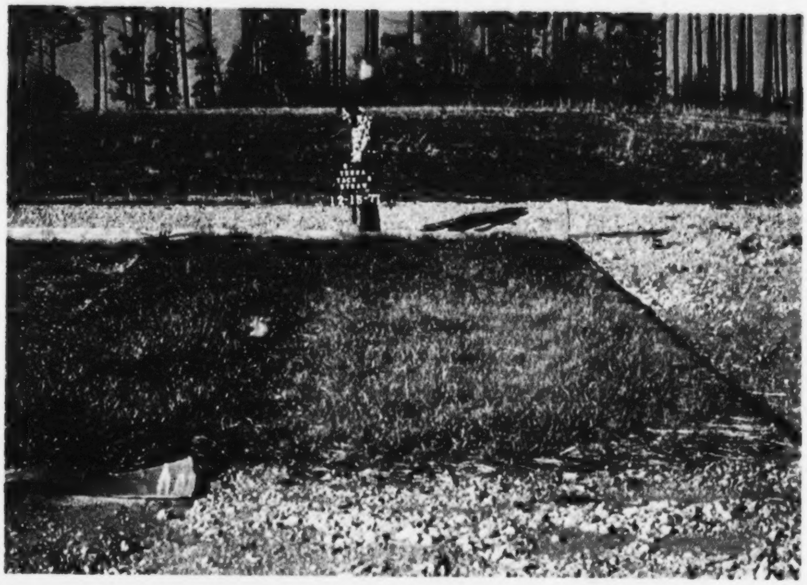


Plot C-19 (a). This plot was treated with straw and Terra Tack II, which we believe was not sufficiently mixed to become effective. In spite of this malfunction, the distribution of straw was not severely affected (October 28, 1977).



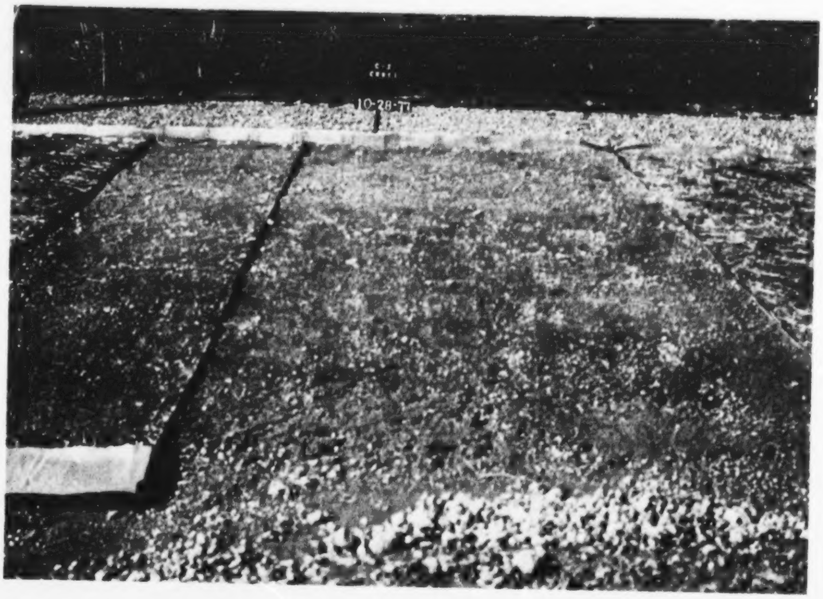
(b). Appearance on November 28, 1977.

PLATE 19 (Continued)
PLOT C-19; TERRA TACK II AND STRAW

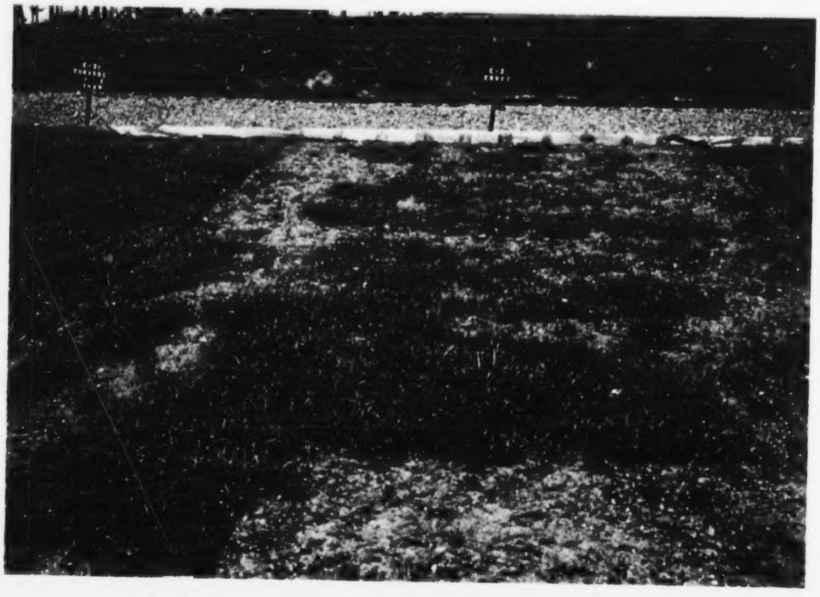


(c). Appearance on December 15, 1977.

PLATE 20
PLOT C-20; CRUST 500 WITH WOOD MULCH FIBER

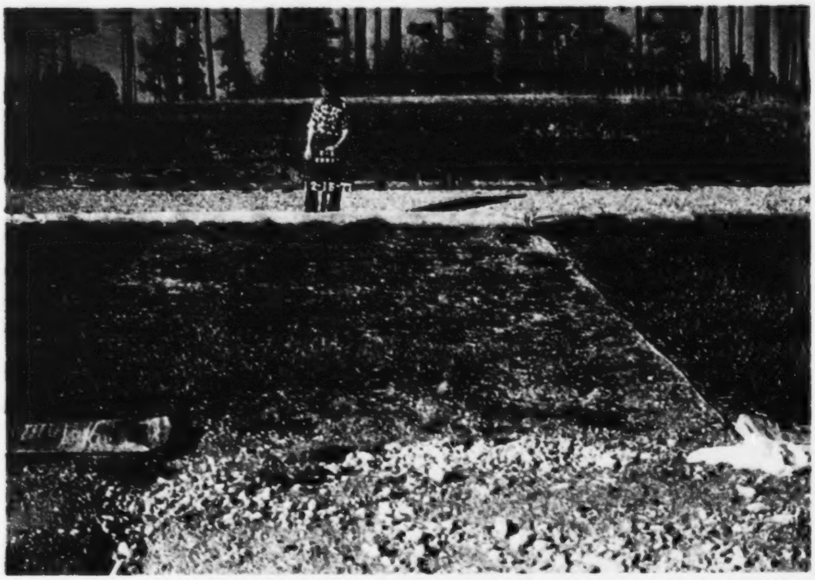


Plot C-20 (a). This treatment, following application, caused the surface of the plot to become encrusted, whereby all of the soil particles were bound together. Appearance on October 28, 1977.

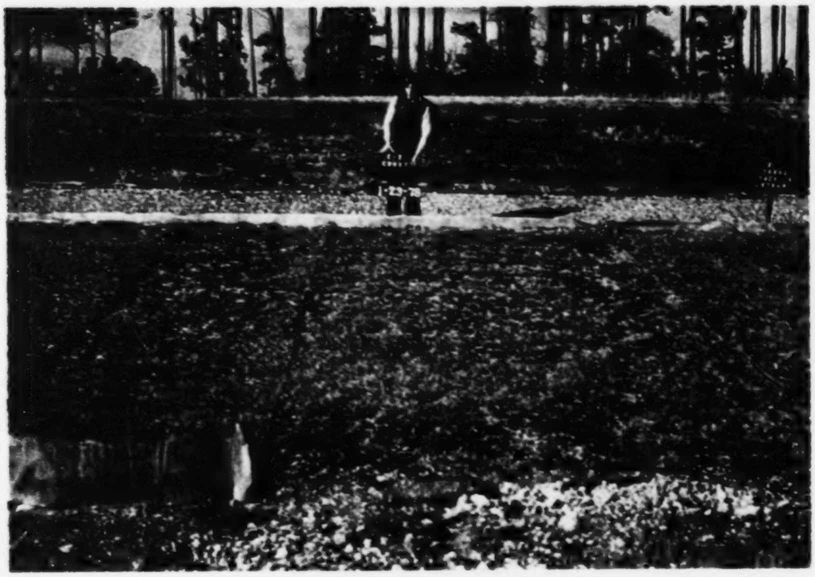


(b). Appearance on November 28, 1977.

PLATE 20 (Continued)
PLOT C-20; CRUST 500 WITH WOOD MULCH FIBER

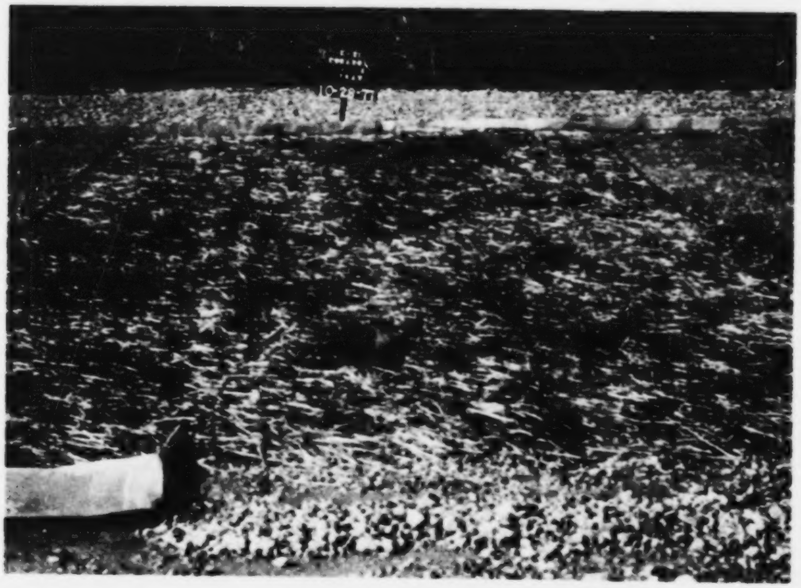


(c). Appearance on December 15, 1977.

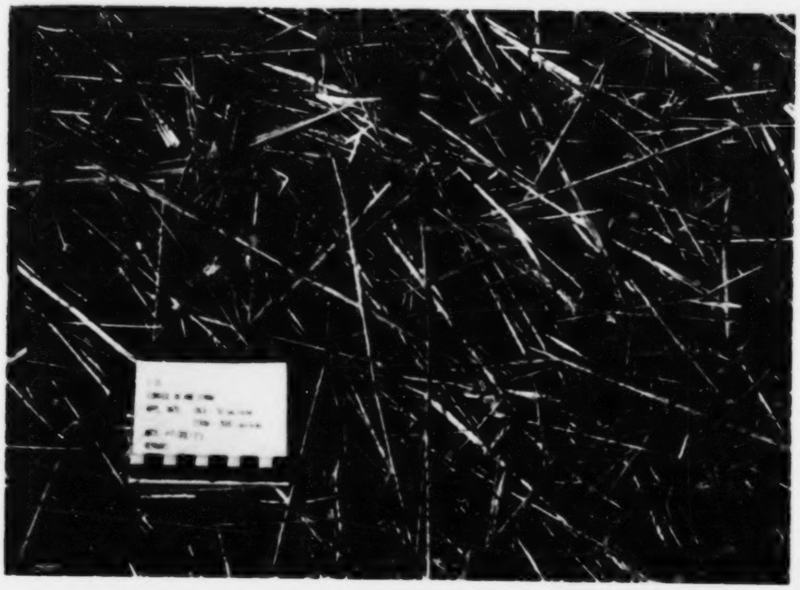


(d). Appearance on January 23, 1977.

PLATE 21
PLOT C-21; CURASOL AK AND STRAW

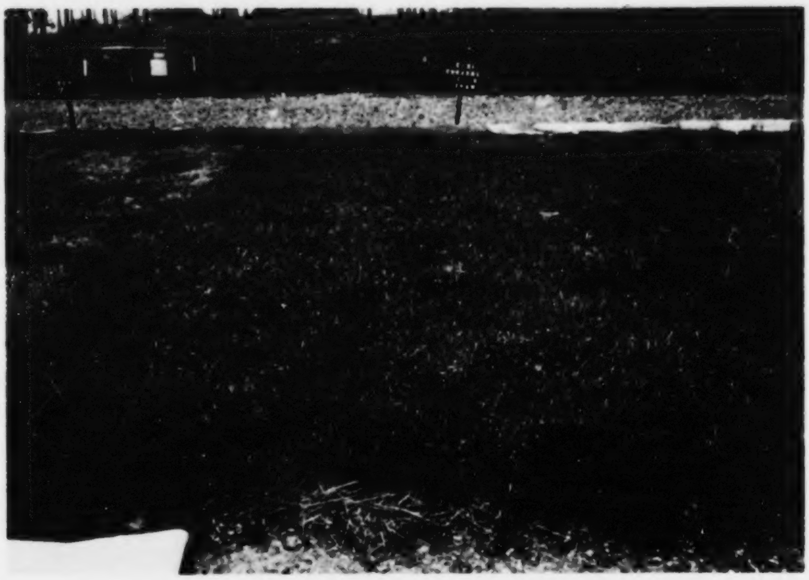


Plot C-21 (a). This plot exhibited good seedling distribution (October 28, 1977).



(b). Close-up of ground coverage afforded by straw and seedling distribution (October 28, 1977).

PLATE 21 (Continued)
PLOT C-21; CURASOL AK AND STRAW



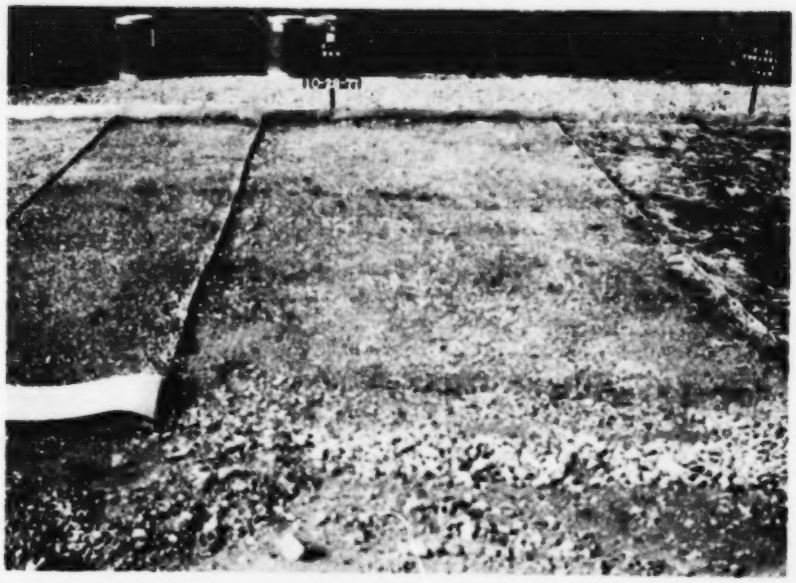
(c). Appearance on November 28, 1977.

(d). Appearance on December 15, 1977.

PLATE 21 (Continued)
PLOT C-21; CURASOL AK AND STRAW

(e). Appearance on January 23, 1978.

PLATE 22
PLOT C-22; DOW MULCH BINDER WITH WOOD FIBER MULCH



Plot C-22 (a). Following application, we noticed that a crust had formed on the soil surface.

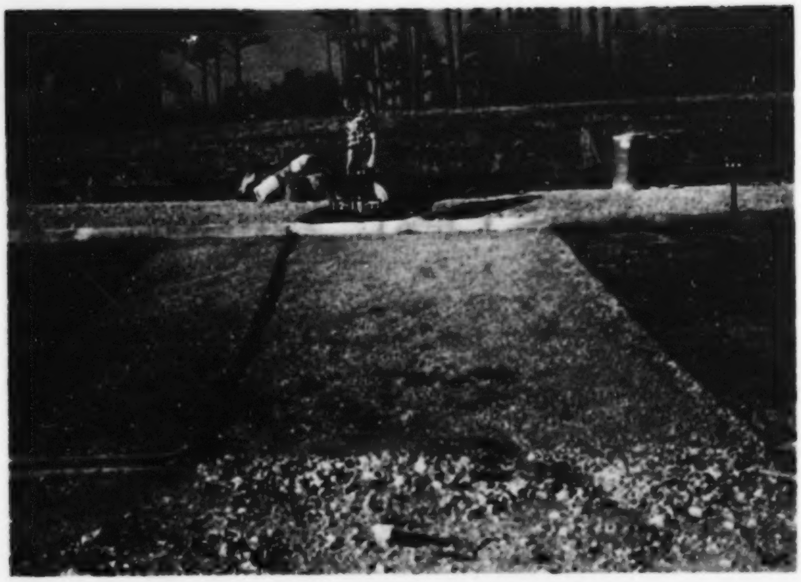
(b). Appearance November 28, 1977.

PLATE 22 (Continued)
PLOT C-22; DOW MULCH BINDER WITH WOOD FIBER MULCH

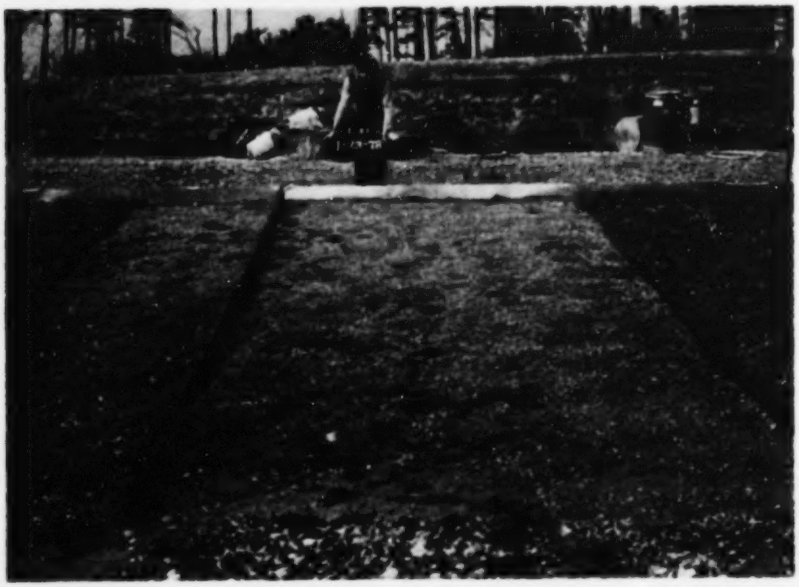
(c). Appearance on December 15, 1977.

(d). Appearance on January 23, 1978.

PLATE 23
PLOT C-23; UNTREATED

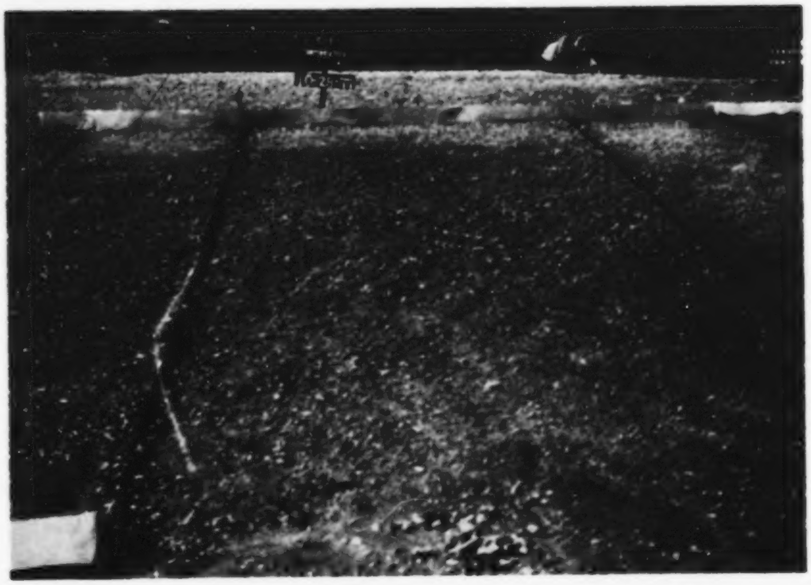


Plot C-23 (a). Appearance of plot on December 15, 1977. This plot was designated as an untreated and unseeded control.



(b). A small quantity of seed was spilled at the base of the plot during application on an adjacent plot. All the vegetation growing on the plot can be attributed to the spill. This further substantiates the effectiveness of measures taken to eliminate growth of volunteer vegetation.

PLATE 24
PLOT C-24; CONTROL FOR "C" HILLSLOPE



Plot C-24 (a). This plot was chosen for the control on the "C" hillslope. Only the standard lime, fertilizer and seed mixture was applied. Of all the control plots, this one exhibited the most intense gulleying (October 28, 1977).

(b). Appearance on November 28, 1977.

PLATE 24 (Continued)
PLOT C-24; CONTROL FOR "C" HILLSLOPE

(c). Appearance on December 15, 1977.

(d). Appearance on January 23, 1978.